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An Introduction to Seaplane Porpoising

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I. Introduction

THE following has been written as an introduction to the problem of porpoising. It does not offer a solution of this complex question but may serve to give a better understanding of the factors involved, to provide a basis for further research, and to help bring the subject into the scope of the engineering office.

Acknowledgments are due to the Advisory Committee of the Richard Hoyt Memorial Seaplane Fellowship,* at whose instigation and under whose general auspices the study was undertaken, and to those who have supplied special data concerning the Courtney Amphibian and the N.A.C.A. Model 40 Series hulls.†

The following symposium of practical opinion has been condensed from the written comments of those who have had many contacts with porpoising.‡

Symposium of Practical Opinion

(1) Seaplane porpoising may be defined as an oscillatory combination of pitching and vertical motion of increasing amplitude.

(2) Porpoising occurs both in alighting and take-off, although the latter may be more serious since the plane remains at a critical speed for a longer time.

(3) Porpoising during alighting occurs, ordinarily, after the speed has begun to drop but before the ship "displaces" or goes off the step.

(4) Porpoising may be roughly placed in two classes; one class which can be counteracted by applying a steady load on the horizontal tail surfaces and thus passing to another angle of trim; and one which can only be counteracted (if it can be) by the alternate application of up and down loads on the tail surfaces.

(5) In general, an empirical rule is to get "through" the porpoising region as quickly as possible.

(6) Definite cases of curing porpoising by moving the step aft are reported; but equally definite cases are reported where improvement was obtained by moving the step forward.

(7) There is apparently a phenomenon quite different from porpoising which is termed leaping, or bouncing. One observer wrote, "Somewhat different than porpoising, yet of the same nature, is a skipping or bouncing tendency, at or slightly under take-off speed." In a detailed report of systematic tests on C.G. variation with a Courtney Amphibian equipped with Edo floats, Korvin-Kroukovsky writes: "It is evident that porpoising improved and finally disappeared as the center of gravity moved aft. However, as the typical porpoising disappeared, there still remained the tendency to bounce off occasionally in adverse conditions before flying speed was reached, and it appears that this bouncing tendency disappeared, or at least was not encountered in the process of tests, only when the C.G. was moved to within $\frac{1}{2}$ inch from the step or 36.4 percent of the mean chord. . . .Excessive flight stability may be a cause of porpoising or bouncing."

Presented at the Airplane Design Session, Seventh Annual Meeting, I. Ae. S., January 27, 1939.

* B. V. Korvin-Kroukovsky, William Schwendler, Igor Sikorsky, and T. P. Wright.

† G. W. Lewis, B. V. Korvin-Kroukovsky, George Page, and E Molloy.

‡ E. T. Allen, Daniel Brim, Jr., Ralph Cram, B. V. Korvin-Kroukovsky, George B. Post, Holden C. Richardson, Charles B. Ripley, and Herman C. Wieben.

II. Equations of Motion and Stability Criteria

Since the seaplane in porpoising performs no evolutions in space, it is preferable to work with fixed axes as shown in Fig. 1.

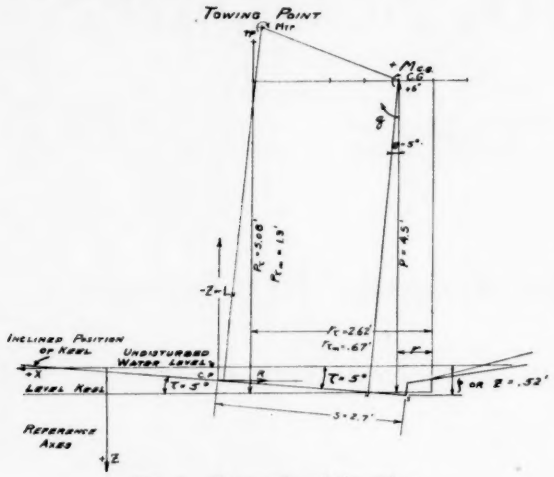

Fig. 1. Geometric relationships.

In writing the equations of motion, the following assumptions are made:

(1) Slip stream effects need not be taken into account.

(2) The velocity along the axis OX is constant, and thrust variations need not be taken into account.

(3) There is initial equilibrium, before the beginning of a disturbance of any kind. Perring and Glauert[1] have studied the validity of these assumptions.

The equations of motion then become, in the customary terminology of the dynamic stability of the airplane in which force and moment derivatives are referred to unit mass and unit moment of inertia, respectively:

$$\begin{aligned} dw/dt &= Z_w w + Z_z z + Z_q q + Z_\theta \theta \\ dq/dt &= M_w w + M_z z + M_q q + M_\theta \theta \end{aligned} \tag{1}$$

where $w = dz/dt$ and $q = d\theta/dt$. The derivatives Z_z and M_z have no analogy in the stability of the airplane where small changes in altitude have no effect on the aerodynamic characteristics, whereas for a float, depth of immersion obviously affects the hydrodynamic characteristics.

The Determinantal Equation becomes, writing $\lambda = d/dt$:

$$\begin{vmatrix} \lambda^2 - Z_w\lambda - Z_z & -(Z_q\lambda + Z_\theta) \\ -(M_w\lambda + M_z) & \lambda^2 - M_q\lambda - M_\theta \end{vmatrix} = 0 \tag{2}$$

and if this is put into the form $A\lambda^4 + B\lambda^3 + C\lambda^2 + D\lambda + E = 0$, the following expressions for the coefficients follow:

$$\begin{aligned} A &= 1 \\ B &= -(Z_w + M_q) \\ C &= -(Z_z + M_\theta - Z_w M_q + Z_q M_w) \\ D &= Z_z M_q - Z_q M_z + Z_w M_\theta - Z_\theta M_w \\ E &= Z_z M_\theta - Z_\theta M_z \end{aligned} \tag{3}$$

Perring and Glauert have established these equations in convenient non-dimensional form, but for the purposes of a "practical" investigation such as presented here, it appears preferable to employ dimensional derivatives.

The well known criteria of stability, for a fourth order equation such as the above are: A, B, C, D, and E must be positive and $R = BCD - AD^2 - B^2E > 0$.

With a fourth order equation, solutions are of the form

$$Z = C_1 e^{(a+ib)t} + C_2 e^{(a-ib)t} + C_3 e^{(c+id)t} + C_4 e^{(c-id)t} \tag{4}$$

$$\theta = C_5 e^{(a+ib)t} + C_6 e^{(a-ib)t} + C_7 e^{(c+id)t} + C_8 e^{(c-id)t} \tag{5}$$

Thus solutions for Z and θ probably represent two oscillations for each variable, which may be out of phase but will have the same periods.

When the terms involving angular motion are dropped from the equation of motion along the OZ axis (Eq. 1), the resultant motion is evidently stable. Similarly, when the linear terms are left out of the pitch equation, the resulting equation represents stable or aperiodically unstable motion, depending upon the sign of the derivative M_θ. Even when both of these independent motions are stable, the combined motion represented by the complete equations may be quite unstable due to the presence of the derivatives Z_q, Z_θ, M_z, and M_w, which are termed cross-coupling terms. On the other hand, even if the independent pitch equation is unstable, the cross-coupling may produce stability in the combined motion.

III. The Calculation of Aerodynamic and Hydrodynamic Derivatives

From theoretical considerations set forth by British writers, and from such meager experimental data as are available, the following assumptions are made:

(1) The fundamental, horizontal velocity is constant, and all derivatives such as M_u, Z_u disappear.

(2) Thrust and slip stream need not be taken into consideration in the equations of motion.

(3) In establishing hydrodynamic derivatives, from towing basin data, Froude's Law or the laws of dimensional similarity should be observed, even though there is a modern tendency to disregard Froude's Law in examining high speed planing phenomena.

(4) In establishing hydrodynamic derivatives, analogies with airfoil laws and conceptions are practicable, within certain limits.

Aerodynamic Derivatives

The formulas given below are derived in references (2) and (3).

$$C_z = -C_L$$

$$Z_w = \frac{\rho}{2}\frac{SV}{m}\frac{\partial C_z}{\partial \theta} = -\frac{\rho}{2}\frac{SV}{m}\frac{dC_L}{d\alpha} \tag{6}$$

$$M_w = +\frac{\rho}{2}\frac{SVc}{m}\frac{dC_{M_{C.G.}}}{d\alpha} \tag{7}$$

$$Z_q = 0$$

$$M_q = (1.25/mk^2)\partial M_t/\partial q \tag{8}$$

$$M_q = 1.25\left[\frac{\rho}{2}\frac{S_t l_t^2}{mk^2} V\left(\frac{dC_L}{d\alpha}\right)_t\right] \tag{9}$$

Where

- 1.25 = Empirical factor
- l_t = Tail arm
- S_t = Horizontal tail area
- θ = Angle of pitch, negative in glide, expressed in radians
- α = Angle of attack, expressed in radians
- m = Mass of the seaplane
- mk^2 = Moments of inertia about a transverse axis through the center of gravity
- k = Radius of gyration about a transverse axis through the center of gravity
- V = Steady, horizontal velocity in ft. per sec.
- S = Wing area
- ρ = Air density
- w = Velocity along OZ axis
- $(dC_L/d\alpha)_t$ = Slope of lift curve of tail obtained from tests at two stabilizer settings, α is in radians

Hydrodynamic Derivatives

It is improbable that sufficient information will be obtainable from a "specific" towing basin test; and a "complete" towing basin test, such as that described in reference 4, should be available.

Non-dimensional coefficients are expressed as follows:

Load, $C_\Delta = \Delta/Wb^3$
Resistance, $C_R = R/Wb^3$
Moment, $C_M = M/Wb^4$
Speed, $C_v = V/\sqrt{gb}$
Trim angle = τ expressed in radians
Draft = $\zeta_d = \zeta/b$

Where

- b = Beam
- d = Draft
- W = Weight of a cubic foot of water
- L_H = Δ = Hydrodynamic lift

Moments of the model test should be transferred to the actual center of gravity of the seaplane under investigation.

Derivative Z_z or Z_ζ. The derivative expresses the change in displacement per unit mass when there is a slight change in draft, without change in trim or speed. Hence:

$$Z_z = Z_\zeta = -\frac{1}{m}\frac{\partial L_H}{\partial \zeta} = -\frac{Wb^2}{m}\frac{\partial C_\Delta}{\partial \zeta_d} \tag{10}$$

The value of $\partial C_\Delta/\partial\zeta_d$ is obtained by cross-plotting C_Δ against ζ_d at the appropriate constant C_v and τ from the original curves of a complete test. Since $\partial C_\Delta/\partial\zeta_d$ is always positive, it follows that Z_ζ will normally be negative.

Derivatives Z_w(and Z_τ). This derivative expresses the change in displacement when the float experiences a vertical velocity. In the conceptions of Perring and Glauert[1] and of Perring and Johnston[5] the expression for this derivative may be written, by analogy with similar aerodynamic derivatives as

$$Z_w = \frac{1}{m}\frac{\partial Z}{\partial \tau}\frac{d\tau}{dw} = -\frac{1}{m}\frac{\partial L_H}{\partial \tau}\frac{1}{V} = -\frac{1}{V}\frac{Wb^3}{m}\frac{\partial C_\Delta}{\partial \tau}$$

and, defining Z_τ as $\partial Z/\partial\tau$, $Z_w = 1/VZ_\tau$. The value of $\partial Z/\partial\tau$ (or $\partial C_\Delta/\partial\tau$) is obtainable by obvious methods from the curves or tabulations of a complete test of the hull. In this derivative appropriate values of C_v and ζ must be maintained. Since $\partial C_\Delta/\partial\tau$ is generally positive, it follows that Z_w will generally be negative.

Derivative Z_θ. Since pitch about the center of gravity is accompanied by a change in draft as well as in angular position, the expression for this derivative is

$$Z_\theta = \frac{1}{m}\frac{\partial Z}{\partial \tau}\frac{d\tau}{d\theta} + \frac{1}{m}\frac{\partial Z}{\partial \zeta}\frac{d\zeta}{d\theta} = Z_\tau + Z_\zeta\frac{d\zeta}{d\theta}$$

Remembering that $d\tau/d\theta = 1$ and making use of Eqs. (10) and (11),

$$Z_\theta = -\frac{Wb^3}{m}\frac{\partial C_\Delta}{\partial \tau} - \frac{Wb^3}{m}\frac{\partial C_\Delta}{\partial \zeta_d}\frac{d\zeta}{d\theta} \tag{12}$$

The value of $d\zeta/d\theta$ is obtained from the geometry of the aircraft in a manner to be described later. The first part of the expression for Z_θ will certainly be negative, but since a positive pitch may either diminish or increase the draft, the second part may be negative or positive. The value of Z_θ is however almost certain to be negative.

Derivative Z_q. In aerodynamic studies, Z_q is generally neglected. It should be accurate enough to evaluate it on the following assumptions:

(1) The direct effect of angular velocity about the center of pressure of the planing surface may be neglected.

(2) The Z force is considered as acting at the center of pressure of the immersed length, with so-called "hydrodynamic chord" drawn from the bottom and rear edge of the step, along the keel to the center of pressure.

(3) The effect of angular velocity about the center of gravity of the seaplane, may then be taken into account by allowing for the increase in the velocity V, and the production of a velocity w by such angular motion.

(4) The effects of angular velocity on R in changing Z may be neglected.

With these assumptions

$$Z_q = \frac{1}{m}\frac{\partial Z}{\partial u}\frac{du}{dq} + \frac{1}{m}\frac{\partial Z}{\partial w}\frac{dw}{dq}$$

In evaluating $\partial Z/\partial u$ one can write $Z = CV^2$, $\partial/\partial u = \partial/\partial V$, $C = Z_0/V^2$ (where Z_0 = initial value of Z) so that $\partial Z/\partial u = 2CV = 2Z_0/V$. Then

$$Z_q = \frac{1}{m}\frac{2Z_0}{V}\frac{du}{dq} + \frac{1}{m}Z_w\frac{dw}{dq} \tag{13}$$

The expressions du/dq and dw/dq can be evaluated by considering the geometrical configuration, as will be discussed later.

Derivative M_z. Analogous to the Z_z derivative, M_z expresses the change in the hydrodynamic moment when there is a slight change in draft, without change in trim or speed. Since moments are referred to unit moment of inertia

$$M_z = \frac{Wb^4}{mk^2}\frac{\partial C_m}{\partial z} = \frac{Wb^3}{mk^2}\frac{\partial C_m}{\partial \zeta_d} \tag{14}$$

In using the data from a complete test, it is of course necessary to transfer moments to the center of gravity of the seaplane. Simplified methods for such transfer are indicated in reference 4. Moments must be obtained at constant C_v and τ and plotted against draft.

Derivative M_w. Proceeding as for the derivative Z_w

$$M_w = \frac{1}{mk^2}\frac{\partial M}{\partial \tau}\frac{d\tau}{dw} = \frac{1}{mk^2}\frac{\partial M}{\partial \tau}\frac{1}{V} = \frac{M_\tau}{V} \tag{15}$$

Derivative M_θ. As in the case of the derivative Z_θ, allowance must be made for the fact that a pitch about the center of gravity is accompanied by a change in draft as well as in angular position. Hence

$$M_\theta = \frac{1}{mk^2}\frac{\partial M}{\partial \tau}\frac{d\tau}{d\theta} + \frac{1}{mk^2}\frac{\partial M}{\partial z}\frac{dz}{d\theta} = M_\tau + M_z\frac{dz}{d\theta}$$

$$= \frac{Wb^4}{mk^2}\frac{\partial C_m}{\partial \tau} + \frac{Wb^3}{mk^2}\frac{\partial C_m}{\partial \zeta_d}\frac{d\zeta}{d_\theta} \tag{16}$$

The sign of M_θ depends on C.G. position in relation to the step, and may be either positive or negative.

Derivative M_q. The evaluation of M_q is similar to the evaluation of Z_q.

$$M_q = \frac{1}{mk^2}\frac{\partial M}{\partial q} = \frac{1}{mk^2}\frac{\partial M}{\partial u}\frac{du}{dq} + \frac{1}{mk^2}\frac{\partial M}{\partial w}\frac{dw}{dq}$$

In evaluating $\partial M/\partial u$, write $M = KV^2$, $\partial/\partial u = \partial/\partial V$, $K = M_0/V^2$ (where M_0 = initial value of M) so that $\partial M/\partial u = 2KV = 2M_0/V$. Then

$$M_q = \frac{1}{mk^2}\frac{2M_0}{V}\frac{du}{dq} + \frac{1}{mk^2}M_w\frac{dw}{dq} \tag{17}$$

Evaluation of $d\zeta/d\theta$. The evaluation of $d\zeta/d\theta$ for any condition under investigation is illustrated by the diagram of Fig. 1. In this diagram the line C.P.-S is the line of the keel, drawn from the bottom edge of the step S, which is taken arbitrarily as a "hydrodynamic chord" line for the float.

C.G.-N is the perpendicular drawn from the center of gravity of the hydrodynamic chord, which has a length p.

r is the distance of the foot of the perpendicular to the point S.

s is the distance of the C.P. on the chord from the point S.

ζ is the draft or depth of the point S below the undisturbed water line of the hull.

θ is the angle between vertical and the perpendicular C.G.-N. This is also the angle which the "hydrodynamic chord" makes with the undisturbed water line.

Then

$$\frac{d\zeta}{d\theta} = \frac{d}{d\theta}(p\cos\theta + r\sin\theta) \cong -p\theta + r \tag{18}$$

Evaluation of du/dq. The distance from the C.G. to the C.P., projected on the OY axis is equal to $p\cos\theta - (s - r)\sin\theta = du/dq$.

Hence $du/dq \cong p - (s - r)\theta$ (19)

Evaluation of dw/dq. The distance from the C.G. to the C.P., projected on the OX axis is equal to $p\sin\theta + (s - r)\cos\theta = dw/dq$.

Hence $dw/dq \cong p\theta + (s - r)$ (20)

Transfer of Moments to the Center of Gravity

It is convenient to introduce the dimensions:

p_t = perpendicular from the towing point T.P. on the "hydrodynamic chord."

r_t = distance from the foot of the perpendicular from T.P. to the "hydrodynamic chord."

and to recall that L_H = hydrodynamic lift or displacement

Then

$$M_{C.G.} = M_{T.P.} + (L_H\cos\theta + R\sin\theta)(r_t - r) + (R\cos\theta - L_H\sin\theta)(p - p_t) \tag{21}$$

Using this relation,

$$M_z \cong \frac{1}{mk^2}\frac{\partial M_{T.P.}}{\partial z} - \frac{Z_z}{k^2}(r_t - r) \tag{22}$$

$$M_\tau = \frac{1}{mk^2}\frac{\partial M_{T.P.}}{\partial \tau} + \frac{\partial}{\partial \tau}[(L_H\cos\theta + R\sin\theta)(r_t - r) + (R\cos\theta - L_H\sin\theta)(p - p_t)] \tag{23}$$

$$\cong \frac{1}{mk^2}\frac{\partial M_{T.P.}}{\partial \tau} - \frac{Z_z(r_t - r)}{k^2} \tag{24}$$

The position of the center of pressure,

$$s = \frac{M_{C.G.} + (R\cos\theta - L_H\sin\theta)p}{L_H\cos\theta + R\sin\theta} \tag{25}$$

$$= [M_{T.P.} + (L_H \cos\theta + R \sin\theta) r_t + (R \cos\theta - L_H \sin\theta) p_t] / [L_H \cos\theta + R \sin\theta] \quad (26)$$

IV. Characteristics of the Amphibian Flying Boat Used in Calculations

A system of non-dimensional derivatives for use in porpoising calculations has been developed[1] but in the initial stages of porpoising research, and in the work of the practicing engineer, there is considerable advantage in concentrating on a definite machine. The machine selected for experimental calculations here is the Courtney Amphibian. Unfortunately the hull of the Courtney Amphibian is not of a type for which complete tank tests are available. Two hulls tested by the N.A.C.A.[4] and described as the N.A.C.A. model 40 series of flying boat hulls consisting of two forebodies and one afterbody, (1) Model 40-AE: Forebody with hollow bow sections (non-developable)—no step after body, and (2) Model 40-BE: Forebody with bottom surface completely developable from bow to step—no step afterbody, were therefore employed in these calculations. Since the Courtney Amphibian hull is different from either of these hulls, it cannot be said that the investigation applies to the Courtney Amphibian, but merely of a machine which is representative of this size and type of seaplane. The published curves[4] are not on a large enough scale for calculation, so that original tabulations were generously supplied by the N.A.C.A.

Main Dimensions of the Courtney Amphibian

The main dimensions and characteristics so far as they are of interest are as follows:

Gross Weight = 4230 lb.
Upper Wing
Span = 40 ft.; Chord = 60 in.; Area = 194 sq.ft.
Lower Wing
Span = 35 ft.; Chord = 60 in.; Area = 169 sq.ft.
Normal position of the center of gravity 6 in. forward of the step and 53.9 in. above the keel
Horizontal tail surface area = 47.2 sq.ft.
Arm from center of gravity to rudder post = 200 in.

	Float	Model
Length of hull	23 ft. 6 in.	100 in.
Distance from bow to step (forebody)	151 in.	42 in.
Distance from step to stern (afterbody)	132 in.	58 in.
Angle of rise of the afterbody	7°	8° 30′
Angle of deadrise	18° 0′	20°
Beam	4.25 ft.	13 in.
Depth of hull	5.25 ft.	14 in.
Depth of step	3.75 in.	0.5 in.

Lines and characteristics of floats employed in the experimental calculations are fully described in reference 4.

V. Calculations with the Model 40-AE Hull

In this series of calculations, the Courtney Amphibian was taken to be equipped with the Model 40-AE hull as described in reference 4. The speed for which the calculations were made was assumed to be 45 m.p.h. or 66 ft. per sec. a speed at which porpoising difficulties had been encountered in the flight tests. The condition of operation is defined by the following:

Beam over chine = 4.25 ft.
$C_v = V/\sqrt{gb} = 5.65$
Mass moment of inertia = 5350 lbs. ft.
Best trim angle as determined from ref. 4, $\tau = 5°$
Angle of attack of wings = 9°
$C_L = 0.64$ at 9°
Hydrodynamic lift, L_H = 2980 lbs.
Normal position of C.G. determined by $p = 4.5$ ft., $r = 0.5$ ft. (see Fig. 1)
θ_0 = Initial angle between vertical and line from C.G. perpendicular to "hydrodynamic chord" = 5°
Draft ζ = Vertical distance from undisturbed water line to lower edge of step = 0.52 ft. with $\zeta_d = 0.122$.
Center of pressure as defined by Eq. (24), $s = 2.7$ ft.
Towing point is defined (transferred to full scale) by $r_t = 2.62$ ft., $p_t = 5.08$ ft.

Pertinent hydrodynamic data from towing basin tests, for which the scale was 3.92, gives model weight as $2980/a^3 = 49.5$ lb., and $V_{model} = 66/a^{1/2} = 33.3$ ft. per sec. The beam over chine of the model was 13 in.

The pertinent wind-tunnel data are illustrated in the curves of Figs. 2 and 3. The aerodynamic derivatives without correction for scale, were calculated from these curves.

Towing point (T.P.) for the model is defined by p_t and r_t. (See Fig. 1.) In order to obtain the derivatives, Δ is plotted at constant τ, against ζ in inches for the model at $C_v = 5.65$. From these curves of hydrodynamic lift against ζ at $\tau = 3°, 5°, 7°$; cross plots are drawn of Δ at constant ζ against τ. These two sets are shown in Fig. 4. In a similar manner $M_{T.P.}$ is plotted against ζ at constant τ; and then against τ at ζ corresponding to proper loading. (See Fig. 5.)

The calculations involved in determining the hydrodynamic derivatives and the values obtained for $r = +6$ in. are given in Table 1; and the corresponding aerodynamic derivatives and sum of the two are also given in this table. In Table 2 are listed the values of the constants in the discriminant equation and Routh's Discriminant at $r = +6$ in. The constants, Routh's Discriminant, and elevator angles necessary to maintain the trim of 5° and 7° are plotted in Fig. 6 for several values of r, corresponding to different positions of the C.G.

Roots of the Oscillation

For the case where $r = 18$ in., $\tau = 5°$,

$$\lambda^4 + 4.376\lambda^3 + 111.78\lambda^2 + 19.3\lambda + 1836 = 0$$

from which $\lambda_1, \lambda_2 = 0.375 \pm 4.5i$
$\lambda_3, \lambda_4 = -2.5 \pm 8.0i$

There are two oscillatory motions, both of short period, one of which is heavily damped, and the other is moderately unstable.

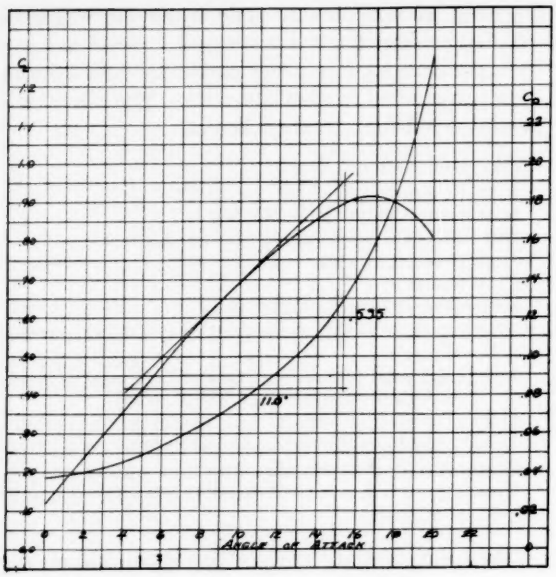

FIG. 2. Lift and drag curves of the Courtney Amphibian. $dC_L/d\alpha = 2.79$ per radian at $\alpha = 9°$.

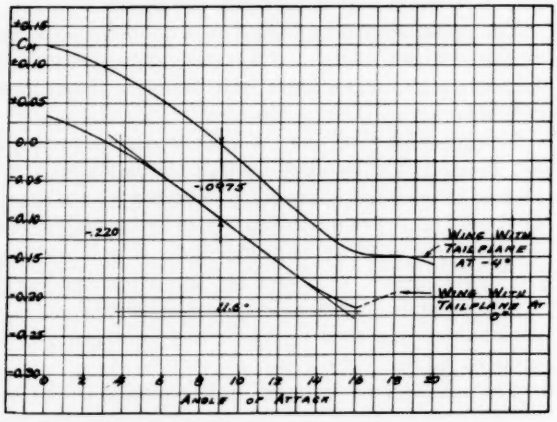

FIG. 3. Moment curves of the Courtney Amphibian. $dC_M/d\alpha_t = -1.40$; $dC_{M_{C.G.}}/d\theta = -1.089$ per radian.

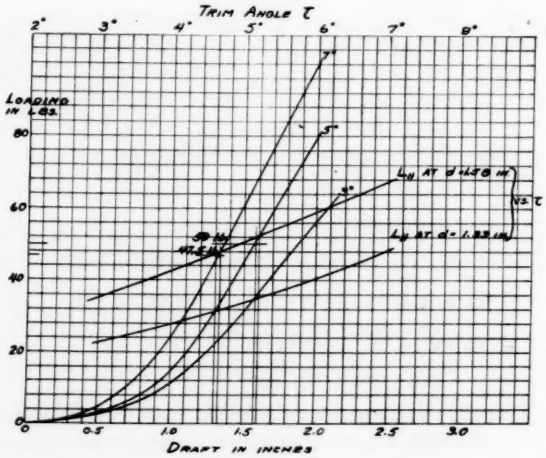

FIG. 4. Lift curves of the N.A.C.A. 40-AE Hull.

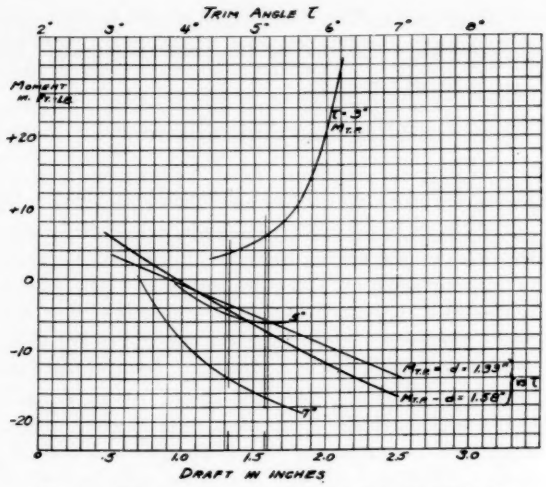

FIG. 5. Moment curves of the N.A.C.A. 40-AE Hull.

These values of the roots are practically the same for all values of r.

It is interesting to calculate also the roots of the independent motion along OZ, and the independent motion in pitch. The equations, obtained by neglecting the cross-coupling terms in Eq. (1), have the roots $\lambda_1, \lambda_2 = -1.9 \pm 10i$ for motion along OZ and $\lambda_3, \lambda_4 = -0.3 \pm 2.4i$ for motion in pitch.

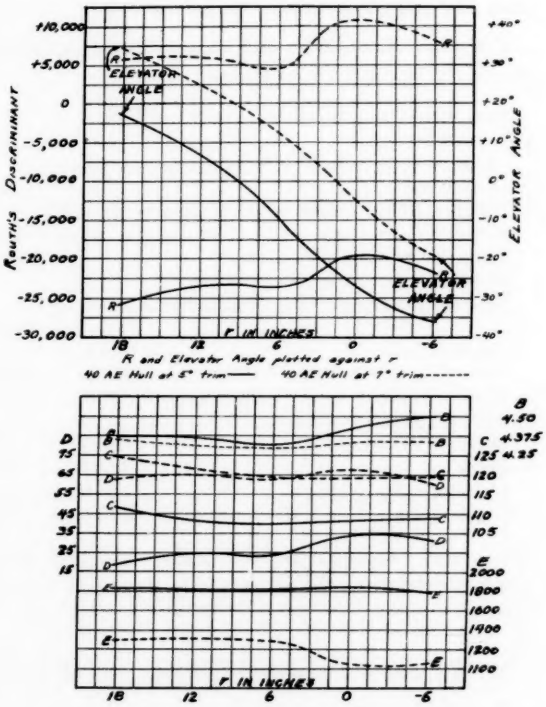

FIG. 6. Routh's discriminant and elevator angle plotted against r and B, C, D, and E plotted against r.

Discussion of Results

The relative values of the various quantities concerned in the value of R are shown in Tables 1 and 2.

TABLE 1. VALUES OF THE GEOMETRIC FACTORS AND DERIVATIVES

(r = +6 in., τ = 5° and 7°)

Derivative	Equation	Hydrodynamic Value	Aerodynamic Value	Total	Total
		τ = 5°		τ = 5°	τ = 7°
$d\zeta/d\theta$	(18)	+ .1		+ .1	− .05
du/dq	(19)	+ 4.35		+ 4.35	+ 4.35
dw/dq	(20)	− 2.6		− 2.6	− 2.05
Z_z	(10)	− 100.	0	− 100.	− 114.
Z_τ	(11)	− 211.		− 211.	− 223.
Z_w	(11)	− 3.2	− .6	− 3.8	− 3.63
Z_θ	(12)	− 221.	−40.	− 261.	− 234.
Z_q	(13)	+ 5.3	0	+ 5.3	+ 3.2
M_z	(22)	+ 4.95	0	+ 4.95	+ 3.92
M_τ	(23)	− 3.85		− 3.85	− 1.29
M_w	(15)	− .058	− .028	− .086	− .05
M_θ	(16)	− 3.35	− 1.92	− 5.27	− 3.32
$M_{C.G.}$	(21)	+4700.		+4700.	+2500.
M_q	(17)	+ .263	− .784	− .521	− .663

It will be observed that the values of the aerodynamic derivatives are on the whole much smaller than the corresponding hydrodynamic derivatives, except for M_q, the damping term due to the tail surfaces. This term is much larger than the hydrodynamic M_q.

In the totals Z_z, Z_w, M_θ, and M_q are all negative. An independent motion in pitch alone or along the vertical axis alone would therefore be stable. Hence, any instability must be accounted for by the effect of the cross-coupling derivatives, M_w, M_z, Z_q, and Z_θ.

The values given in the table apply only to r = 6 in., but the calculations were repeated for several values of r and the important quantities are plotted in Fig. 6. The required moment for trim at 5° and 7° and the necessary elevator displacements to maintain this trim were calculated; the resultant elevator angles are also plotted in the figure.

TABLE 2. CALCULATION OF B, C, D AND E OF DISCRIMINANT EQUATION

r = 6 in.

	τ = 5°	τ = 7°
A	1	1
Z_w	− 3.8	− 3.6
M_q	− .521	− .66
$+B$	+ 4.321	+ 4.29
$+Z_z$	− 100.	− 114.
$+M_\theta$	− 5.27	− 3.3
$+Z_qM_w$	− .45	− .2
$-Z_wM_q$	− 1.98	− 2.4
$+C$	+ 107.50	+ 119.9
$+Z_zM_q$	+ 52.1	+ 75.5
$+Z_wM_q$	+ 20.0	+ 12.2
$-Z_\theta M_w$	− 22.4	− 11.5
$-Z_qM_z$	− 26.2	− 12.5
$+D$	+ 23.5	+ 63.7
Z_zM_θ	+ 527.	+ 380.
$-Z_\theta M_z$	+ 1,290.	+ 916.
$+E$	+ 1,817.	+1,296.
R	−23,600.	+4,600.

It is to be noted that, while the individual values of A, B, C, D, and E show little variation with C.G. position, the effect of angle of trim is considerable. The changes in individual derivatives associated with the change in trim for r = 6 in. are shown in Table 1.

The resultant effect of trim on R is quite marked. For τ = 5°, $R < 0$, corresponding to instability, over the entire range of values of C.G. position. However, for τ = 7°, $R > 0$ throughout the entire range.

VI. EFFECTS OF ARBITRARY CHANGES IN THE DERIVATIVES

It seemed of interest to continue the calculations of the last sections by making arbitrary changes in the four derivatives, Z_z, Z_τ, $M_{T.P._z}$, and $M_{T.P._\tau}$, from which the rest are derived. These four will be referred to as basic derivatives. The new values of Routh's Discriminant

TABLE 3. TABULATION OF CONSTANTS AND ROUTH'S DISCRIMINANT

r = 0

	ΔZ_z		ΔZ_τ		$\Delta M_{T.P._z}$		$\Delta M_{T.P._\tau}$	
	−20	+20	−50	+50	−1.5	+1.5	+5	−5
A	1	1	1	1	1	1	1	1
B	+4.437	+4.437	+5.037	+3.837	+4.437	+4.437	+4.671	+4.203
C	+128.77	+87.77	+104.56	+111.54	+107.67	+108.87	+103.67	+112.84
D	+40.6	+28.0	+5.3	+63.3	+52.5	+26.0	+55.2	+14.6
E	+2240	+1476	+1852	+1874	+1481	+2228	+1358	+2358
BCD	+23,200	+10,900	+2800	+27,000	+22,200	+12,500	+26,800	+6300
$-AD^2$	−1600	−800		−4000	−1800	−700	−3000	−200
$-B^2E$	−44,000	−29,000	−47,000	−27,600	−29,000	−43,800	−29,600	−41,600
R	−22,400*	−18,900	−44,200	−4600	−8600	−32,000	−5800	−35,500

*Original R = −20,300

and constants of the discriminant equation for these new values are listed in Table 3.

Similar calculations were carried out for other positions of the center of gravity, and the variations in the values of the constants were quite small. Thus the table for $r = 0$ may be taken as indicative of all positions.

VII. Conclusions

Although only a single machine in a few attitudes has been studied, the results obtained check with known experiment to a certain extent, so that the method employed and the conclusions reached may be taken tentatively until more experimental work is published

(1) The independent motions in rise and pitch are usually stable in themselves.

(2) Two independent stable motions may be converted to unstable motion by cross-coupling. There is no simple relation between the independent motions and the combined motion. Of the two roots, the periods of the longer and shorter oscillations correspond roughly to the periods of the angular and linear motions, respectively. However, the damping terms are not comparable.

(3) The quite rapid, well-damped oscillation of the combined motion is likely to escape the attention of the pilot. It is the less rapid, slightly damped or unstable oscillation that is likely to draw his attention. Practical opinion is united as regards the difficulty of checking the oscillation. This difficulty is clearly understandable in the light of the previous calculations. First of all the so-called slower oscillation is in reality quite rapid with a period of the order of two or three seconds, so that the pilot would have difficulty in maintaining his efforts in phase. Secondly, the pilot applies elevator in proportion to the pitch, which means increasing the derivative M_θ while it is response to angular velocity M_q which is more helpful.

(4) A survey of practical opinion indicates that there is more porpoising difficulty in take-off than in landing. The reason is that the amplitude of the unstable oscillation increases comparatively slowly. In a take-off with heavy wing loading, a condition of approximately constant speed and trim may persist long enough for the motion to become dangerous. In alighting the seaplane rapidly passes through any condition likely to lead to instability.

(5) Practical opinion indicates that the best way to check porpoising is to pass to a different angle of trim. The calculations indicate that a relatively small change in angle will cause instability to disappear.

(6) Several of the experienced men contributing to the symposium indicate that change in the position of the center of gravity is not a cure-all. Korvin-Kroukovsky's report indicates that in the Courtney Amphibian, porpoising characteristics were progressively improved as the center of gravity was shifted back. All the calculations carried out here appear to indicate that the position of the center of gravity is almost a matter of indifference as far as the stability of motion is concerned. The apparent discrepancy between practical experience and theoretical investigation is explainable. At conditions of operation where porpoising is likely to be encountered, the presence of a large negative value of M_θ in the hull, together with the thrust of the propeller placed well above the center of gravity may make it difficult to bring the hull to a slightly greater angle of trim and so pass out of the unstable region. As the center of gravity is moved back, the pilot exercising the same manual effort, can more readily avoid the critical attitude.

(7) While for the cases considered, the hydrodynamic effects appear to be much more important than the aerodynamic factors, it is quite impossible to neglect the aerodynamic factors. For example the damping of pitch introduced by the horizontal tail surfaces may make all the difference between stability and instability. Porpoising tests of a dynamic model of a hull alone may therefore be very deceptive.

(8) A general rule that seems to be universal in this study is to increase the uncoupled derivatives (Z_z, Z_w, M_θ, M_q) and to decrease the coupled derivatives (Z_θ, Z_q, M_z, M_w). This rule is easy to state but at present not so simple to apply since the derivatives depend upon a complex relationship between hull form and speed. It is possible to predict the effects of certain changes such as beam loading, C.G. position, and trim angle, when a complete test of the hull is available, by carrying through the calculations indicated in this paper.

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Some Structural Problems Pertaining to Pressurized Fuselages

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WITH the advent of pressurized airplane cabins a number of new problems are presented to the stress analyst. It is the purpose of this paper to discuss a few of these problems.

Suitable Cross-Sectional Shapes for the Pressure Container

For weight economy it is necessary that the internal pressure be retained by circular elements wherever possible. The complete circle is, of course, ideal from a pressure retaining standpoint, but is not always the most suitable for the space distribution required. One method of obtaining considerably greater depth than width is by means of a section consisting of two nonconcentric arcs. The floor serves as the stay member between the points of intersection. This shell contour permits considerable concentration of pay load near the center of gravity, since it makes available suitable space beneath the floor for deep baggage and freight compartments.

Fig. 1 shows three cross-sectional shapes, all having the same enclosed areas and the same centerline head room above the floors. Section B is, of course, narrower at the floor line than section A, but has considerably greater depth in the space below the floor, making this more useful as baggage compartment space. The reduced floor area results in sufficient weight saving to approximately counterbalance the weight necessary to fair the outside lines across the intersection points. This section as compared with A has the aerodynamic advantage that, with the wing just below the floor line, it presents a closer approach to the mid-wing arrangement than is feasible with anything but very large ships having circular fuselages. Toward the rear, the fuselage acquires an inverted pear shape which according to wind tunnel results appears to be aerodynamically beneficial. The advantages of section B appear to decrease by comparison with section A as size of ship increases.

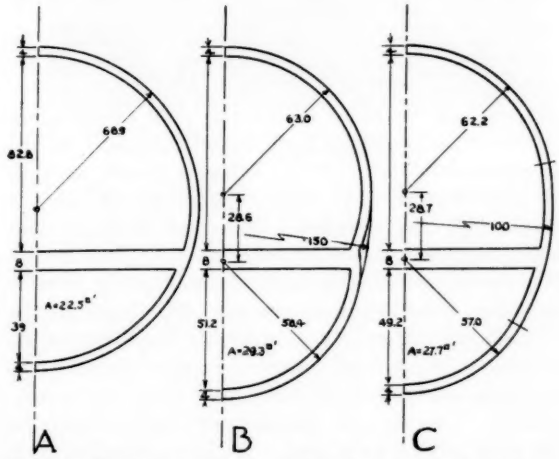

FIG. 1. Cross-sectional shapes for the pressure container.

Section C indicates means, feasible for local regions, to provide greater width at the floor than is the case for section B. It represents a greater weight expenditure than either of the other sections since it involves the support of a certain portion of the load by bending. Fig. 2 indicates the method of calculation for determination of loads in the above-mentioned element of section C. Bending moment at any point p in the region shown is $(R_3 - R_2)PN$ where P is the pressure differential, and N the normal distance of p from the tangent line cd. An appropriately modified equation holds for the upper portion of the arc. In all cases the tension load in the floor equals PH.

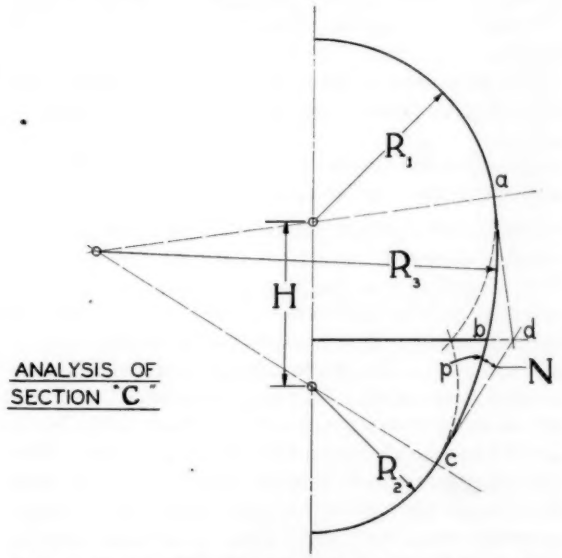

FIG. 2. Data necessary for calculation of stresses in section *abc* of Fig. 1(C).

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The circular section should find favor in very large ships and the double-arc shape where the overall width of the fuselage is less than approximately twelve feet.

Strength Requirements

The loads imposed on any portion of the pressurized shell are a combination of:

(a) Those due to wing, tail, and landing gear reactions,

(b) Those due to useful load or dead weight items located within the fuselage structure, and,

(c) Those due to differential pressure between inside and outside.

The requirements for a satisfactory structure are approximately as follows:

(1) The maximum imposed load likely to occur shall not impair or permanently deform the structure.

(2) A sufficient reserve of ultimate strength should be provided to cover exceptionally severe loading conditions which exceed the assumed probable maximums. This requirement is intended to provide the highest possible degree of ultimate safety, hence some permanent distortion of the structure is of no special concern under these conditions.

(3) The structure should have a margin of strength sufficient to cover a reasonable amount of deterioration in service. This includes such items as wear, fatigue, corrosion, and reduced strength due to normal repair work.

(4) An allowance should be made for normal variations in materials of construction and fabrication processes.

(5) Allowance should be made for uncertainties of analysis methods and criteria.

Loads due to pressurization have certain peculiarities which distinguish them from flight or landing loads. The magnitudes of the imposed loads are very accurately known, and cannot, with the provision of suitable safety valves, be appreciably exceeded. Consideration (2) in the above tabulation will therefore be fulfilled automatically by complicance with (1). Since the structure is subjected to its maximum probable imposed loads for a considerable portion of its service life, this being its normal operating condition, the pressure shell should have an appreciable allowance for fatigue, material creep, etc. In contrast, it is highly improbable that conditions corresponding to the design hypotheses will be encountered by wing, tail, or landing gear for more than a few minutes total time. Normal allowance is ample for variations in material or fabrication and for uncertainties of analysis methods because it is so simple by means of a proof test to check the strength of the shell with an authentic representation of the loads due to pressurization.

A practical design might use the following design load factors:

(1) For a steady flight condition superimpose upon the loads due to normal unaccelerated flight those due to the maximum probable pressure differential, the latter to be multiplied by a constant which would provide for fatigue, creep of the material, and the excess pressure possible before the safety valves can open. This factor should probably be between 1.25 and 1.50. Both flight and pressure loads should then be multiplied by the conventional 1.50 for design purposes.

(2) For momentary accelerations the pressure loads without the factor for fatigue, etc., should be superimposed on the critical limit flight loads. As before, both flight and pressure loads should be multiplied by the factor 1.50 for design purposes.

Pressure Shell Design

Considering the general proportions of a typical transport fuselage, it is rather surprising to note how low the skin gages can be, and yet maintain reasonable design pressure differentials. In Fig. 3 is shown the required skin thickness for various radii of curvature and for various design pressure differentials. In the construction of this chart an ultimate tensile strength of 56,000 lbs. per sq.in. and a rivet seam efficiency of 75 percent were assumed. The chart indicates that major emphasis should probably be placed on the refinement of detail design rather than on saving in basic skin gage, since minimum practical thicknesses are the determining feature in a considerable proportion of the cases. As an inherent feature of pressurization, a considerable refinement of skin joints must be accomplished. Provision for sealing these imposes limits on the rivet patterns to be used. It follows, therefore, that regardless of the pressure differential for which the ship is designed, a considerable increase in cost of the fuselage shell will be encountered. Fortunately, the direct cost and weight penalties increase more slowly as the pressure differential becomes greater. Probably the most important factors restricting the designer to as low pressure differentials as he can make serve his purposes are the penalties incidental to making openings such as doorways and other discontinuities.

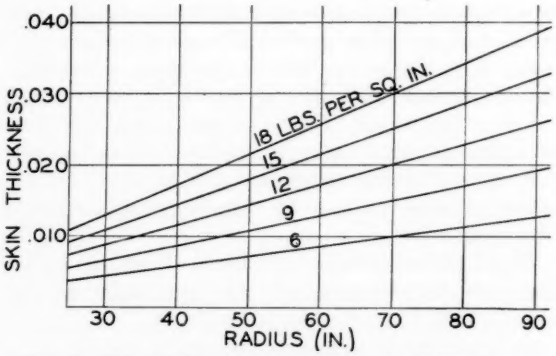

Fig. 3. Skin thicknesses corresponding to 56,000 lbs. per sq.in. ultimate strength and joint efficiency of 75 percent for various design pressure differentials.

Riveted Seams

It is, of course, no simple problem to make an inexpensive, yet efficient, seam to join the sheets of the fuselage shell. For practical reasons it is desirable to use a minimum number of standardized rivet patterns. Where loads to be transmitted by the seam are relatively large, it is generally necessary to devise a high-efficiency joint. The result is a multiple-row pattern with generous spacing of outer-row rivets. It will be found that the most efficient patterns are those which have relatively close spacing of the rivet rows, since, by this arrangement, the difference of stretch between the sheets is reduced to a minimum, and the unit loading on the outermost rivets is not appreciably higher than the average for the entire pattern. The critical spacing of the rows is such that the summation of net distances between adjacent rivet holes is slightly less than the summation of net distances between rivet holes in the outermost row. At this critical spacing the joint efficiency is a maximum. If the sheet is critical, it may fail either across the first row of rivets or along the irregular line joining adjacent rivets. Fig. 4 shows a typical failure of the sheet.

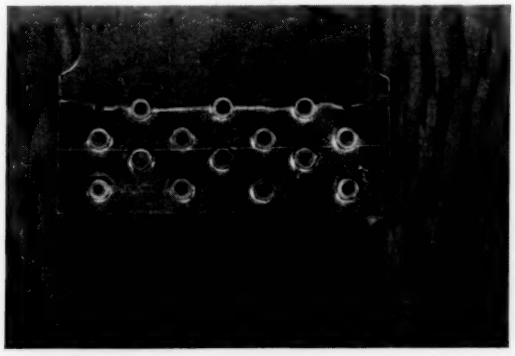

Fig. 4. Typical failure of skin in tension along outermost row of rivets.

Figure 5 shows four typical joints. In the two and three-row patterns the rivets are usually critical in shear or the sheet is critical in bearing, thus the strength can be calculated fairly closely. In the four-row pattern, the joint will develop about 75 percent of the net sheet strength in tension unless the gages are sufficiently high to cause shear failure of the rivets. The alternate pattern at the extreme right compares well with the four-row pattern and, because of its wider spacing of rivets in each row, is better where intersections with other joints occur. To obtain higher efficiencies requires progressively greater complexity of pattern, rapidly departing from that which is practical.

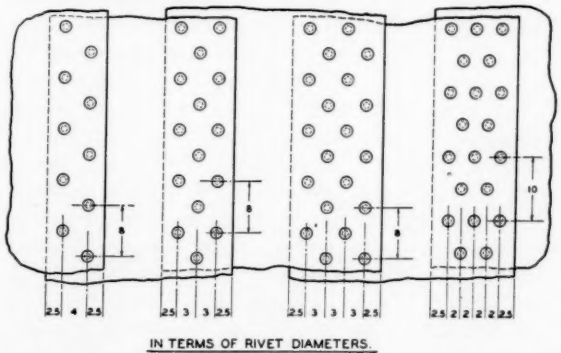

Fig. 5. Representative rivet patterns covering a reasonable range of joint efficiencies.

In Fig. 6, attention is called to a condition which will locally stress the sheet described as C to approximately 15 percent higher than average in the case where A is twice as thick as B or C. At some distance from their intersection, the loads per unit of width in sheets A and B will be equal. With these two joined by their common rivet seam, the difference of deformations will be eliminated locally through a transfer of part of the load from B to A. At section X-X this non-uniform distribution of loading is reflected as a concentration of stresses in C, which, under some conditions might become critical.

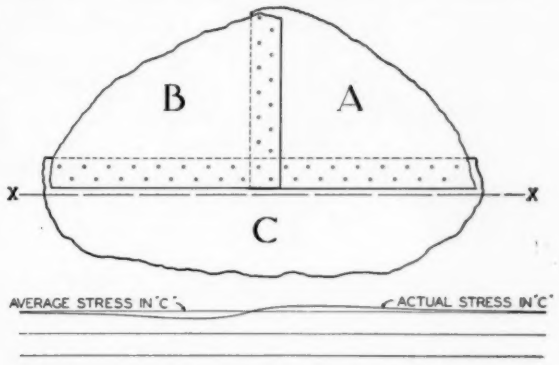

Fig. 6. Illustration of a condition where one sheet (A) is appreciably thicker than its neighbor (B) producing therefore a local increase of stress in the third sheet (C).

Loads and Stresses around Shell Openings

An opening in a cylindrical shell subtending an appreciable arc presents two problems of quite different natures. For typical openings, the more simple of the two is that of carrying the circumferential loads. The loads which may be considered interrupted by the opening will be carried as tension in the ring and skin elements immediately forward and rearward of the opening. Beam-like structures above and below must be provided to effect this redistribution of load. For most normal doorways this member is of a quite moderate size, and presents no difficulty in design. The inward pull of the ring and skin due to tension is offset by the outward force on the door, which must be transmitted to the rings through support flanges, latches, or other suitable means. These doors supports should be well distributed along the sides.

The second and more difficult problem presented by pressurization is that due to the distribution of longi-

tudinal loads around a doorway. It is, of course, necessary to provide sufficient material at top and bottom of the opening to replace that which is cut away. It is also necessary to extend this material sufficiently far fore and aft of the opening to suitably redistribute the loads to the skin without setting up unduly large local stresses. Fig. 7 shows principal stress lines for an upper aft segment of a doorway with a longitudinal reinforcement member extending straight aft over the top of the opening, tapering off to typical stiffener proportions at approximately the right edge of the figure. The continuance of the reinforcement appreciably beyond the opening prevents a sudden inward curving of the principal stress lines. Normal forces are imposed on the shell in proportion to the circumferential component of the principal stresses transmitted through the portion of the shell considered. A study of the figure indicates that the maximum inward load occurs near the top and bottom corners of the opening. Likewise the study indicates that rings other than those adjacent to the opening are also loaded.

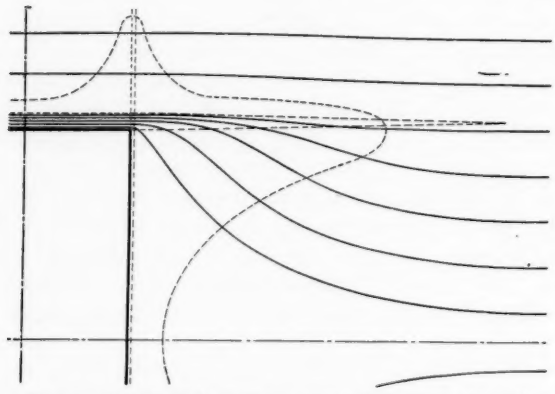

FIG. 7. Principal stress lines around the upper aft portion of a doorway. Broken lines represent approximate areas requiring reinforcement material.

The broken line in the figure indicates very roughly the region where skin reinforcement may be required.

The door itself can be made a relatively simple panel carrying loads as a beam simply supported at its front and rear edges. It may be arranged to open toward the outside or toward the inside. Those that open inward require relatively simple latching mechanisms since the pressure loads are carried by the door frame directly. The greatest objection to this arrangement is that with doors of a size suitable for main entrances of passenger transports the curvature is sufficient to make disposition in the vestibule space when in the open position quite difficult. To carry overhead or to either side on a track reduces considerably the advantages claimed for the inward direction of opening. Doors that open outward require a considerable number of latches sufficiently strong and reliable to carry the pressure loads. Hinging of the door is, however, quite simply accomplished.

Window and Windshield Installation

In the design of window frames where glass is to be used, it is very important to avoid high stresses which might warp these frames. With plastic materials for window panes, a serious problem is that of distortion of the pane itself when subjected to pressure, since in general any suitable plastic has a relatively low modulus of elasticity. At the Curtiss-Wright plant an experimental window pane of 14 × 16 in. net opening was tested for deflections and ultimate strength. The pane was made of $^1/_4$ in. Plexiglas. Deformation of the center portion of this pane was 0.8 in. at 5 lbs. per sq.in. pressure, and failure occurred at 8.5 lbs. per sq.in. Edges were clamped over a $^1/_2$ in. width. Not only are the conditions of edge support and sealing made difficult, but without doubt the window deformations would have considerable adverse effect on the aerodynamic cleanliness of the fuselage. Full consideration must be given to the large changes of temperature with their effects upon sealing and thermal deformations.

Sealing

As the result of considerable testing with specimens duplicating fabrication conditions for the fuselage it has been found that one of the most reliable and at the same time economical methods of sealing is to merely paint the inside surface of the seams with a suitable compound. The latter should have a moderately heavy body and be of a permanently gummy nature which does not become brittle hard with age or at low temperatures of high altitude flight. Where gaps are encountered as at the intersection of the stringer with the pressure rib a coarsely woven strip of cloth can be used as a base for the film of sealing compound.

Doors can be sealed by any suitable method that takes full account of the special problems involved. Neither the door nor the frame can be considered to be especially rigid. The sealing means therefore must accommodate itself to appreciable, relative movement between them. Approximate tightness can be accomplished quite simply by means of a flexible rubber flange attached to the edge of the door with its free edge resting on the door frame. Cabin pressure will press this seal tightly against the frame. Another type of seal is accomplished by inflation of a flat tube to fill out the space between door and frame. The de-icer pumps furnish a convenient pressure supply for this purpose. To offset its apparently greater complexity, this system has the advantage of creating an air tight and therefore sound tight seal even when flying without pressurization. In a test to demonstrate this principle a pressure of as low as 6 lbs. per sq.in. in the tube resulted in satisfactory functioning of the seal for a cabin pressure of 5 lbs. per sq.in.

Altitude Effects on an Uncompensated Rate-of-Climb Meter

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ABSTRACT

The response of an uncompensated climb indicator to a sudden change in rate of climb and the accuracy of the indicated vertical speed during steady flight are treated as functions of altitude. Results of theory, laboratory tests, and flight tests are shown by non-dimensional curves. Agreement of the results is satisfactory. The observed flight responses of a climb indicator after sudden changes from level flight to actual climbs of 750, 1050, and 2150 ft. per min. are shown by curves of indicated and of actual rates of climb against time. Expressed in terms of non-dimensional quantities, these three curves are identical within the accuracy of flight tests.

The only compensation in this instrument is that which counteracts the effect of temperature on the properties of the materials in the pressure gage. The air chamber is thermally insulated. The capillary is a glass tube that is not compensated in any way.

INTRODUCTION

AIRPLANE pilots and aircraft instrument manufacturers are interested in the time interval that is required at any altitude for a rate-of-climb meter to indicate true vertical speed after a change has occurred. Another point of interest concerns the size of errors that may occur in the indicated vertical speed of an uncompensated climb indicator after the climb has been established for a sufficiently long time that dynamic errors have become negligible. Lack of available quantitative data in the literature on this subject led to the present investigation in which the results of theoretical analysis, laboratory tests, and flight tests are compared.

To facilitate an understanding of the results derived from the study, a convenient method for describing certain performance standards of the instrument will be described.

As criterions of performance of the capillary leak type of rate-of-climb indicator, there are two primary coefficients: (1) sensitivity S, which concerns the static calibration, and (2) characteristic time τ, which partly determines the "time lag" that occurs under changing conditions of climb. A third coefficient is the characteristic damping number n, which also affects the "time lag." Usually the value of the damping number is less critical than the value of characteristic time in determining dynamic errors of rate-of-climb meters. The use of the coefficients τ and n has already been discussed by C. S. Draper and the writer in a previous paper.[1] In the present paper the coefficients are defined analytically in terms of the component factors which determine the operation of the climb indicator; and a measure of merit of the instrument under static conditions is added. The latter is defined as

$$S = \text{sensitivity} = \frac{\text{angular deflection of pointer}}{\text{actual vertical speed}} \quad (1)$$

ANALYTICAL EXPRESSION OF SENSITIVITY

The indicated vertical speed v_i of a climb indicator is related to the actual vertical speed v by a differential equation of the form

$$(d^2v_i/dt^2) + b_1(dv_i/dt) + b_0v_i = b_0'Fv \quad (2)$$

This equation is valid when the effect of temperature changes within the instrument can be neglected and correlation of v_i to v can be established for constant vertical speed by the factor

$$F = \text{sensitivity ratio} = v_i/v = \frac{\text{meter reading}}{\text{actual vertical speed}} \quad (3)$$

In terms of the component factors that influence the operation of the instrument the coefficients are

$$b_1 = \frac{C}{\eta_2}\frac{T_1}{V}\frac{P_2}{T_2} + \frac{k}{c} + \frac{A}{V}\frac{AP_1}{c} \quad (4)$$

$$b_0 = \frac{C}{\eta_2}\frac{T_1}{V}\frac{P_2}{T_2}\frac{k}{c} \quad (5)$$

$$b_0' = \frac{M}{R}\frac{P}{T}\frac{A}{c}\frac{E}{F}gD \quad (6)$$

where (as in Fig. 1)

V = chamber volume
C = capillary coefficient
A = effective area of the diaphragm
k = elasticity coefficient of the diaphragm
c = damping coefficient of the meter with the capillary removed
D = linkage ratio $= \theta/x =$ angular deflection of pointer / linear deflection of diaphragm
E = calibration ratio $= v_i/\theta =$ meter reading / angular deflection of pointer
R = universal gas constant $= 8.32 \times 10^7$ ergs.

Presented at the Instruments Session, Seventh Annual Meeting, I. Ae. S., January 25, 1939.

[1] Draper, C. S., and Schliestett, G. V., *Dynamic Errors of the Rate-of-Climb Meter*, Journal of the Aeronautical Sciences, Vol. 5, No. 11, page 426, September, 1938.

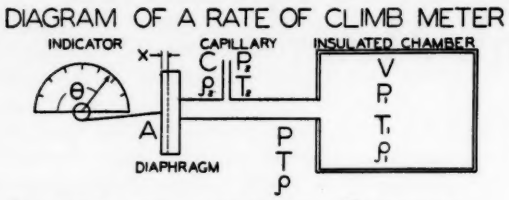

FIG. 1. Diagram of a rate-of-climb meter.

M = molecular weight of dry air = 28.9 gms.
g = acceleration of gravity = 980 cm. per sec.^{2}
η_2 = viscosity of air in capillary = $171 \times 10^{-6} \times (T_2/273)^{3/4}$ gms. per cm. per sec.
T = atmospheric temperature (absolute)
T_1 = temperature inside chamber (absolute)
T_2 = temperature in capillary (absolute)
P = atmospheric pressure
P_1 = pressure inside chamber
P_2 = pressure in capillary

For static conditions the first two terms of Eq. (2) disappear and, since $v_i = E\theta$ by calibration, the equation reduces to

$$b_0 E\theta = b_0' Fv \tag{7}$$

where b_0 and b_0' are made equal by construction of the instrument mechanism but are not analytically identical. By definition, then,

$$S = \text{sensitivity} = \frac{\theta}{v} = \frac{M}{R}\frac{A}{k} gD \frac{V}{T_1}\frac{\eta_2}{C}\frac{T_2}{P_2}\frac{P}{T} \tag{8}$$

The pressure P_2 in the capillary differs from the atmospheric pressure P by a negligible amount and if the temperature T_2 of the capillary is the same as the chamber temperature T_1 of the meter, as in an airplane cabin of constant temperature, then Eq. (8) may be simplified to

$$S = \frac{M}{R}\frac{A}{k} gVD \frac{\eta_2}{C}\frac{1}{T} \tag{9}$$

This expression has terms of three kinds: constants—M, R, C, A, k, g, V, and D; a factor dependent on the temperature of the air in the capillary, η_2; and a term that depends on the manner in which the atmospheric temperature varies with pressure, T.

The indicator itself can be affected only by the atmospheric pressure (which is attained at the instrument by connecting the case to a static tube) and the temperature T_2 which (in a heated cabin) is independent of the temperature T outside the airplane. The climb indicator is sensitive only to the rate of change of pressure, and the indicated vertical speed is associated with this quantity by means of some assumed atmospheric temperature distribution. The deflection θ of the indicator hand for a given rate of change of pressure remains constant as long as the temperature T_2 of the air flowing through the capillary does not change.

The atmospheric temperature T appears in the sensitivity expression only as the result of using the hydrostatic equation

$$dP/dt = -\rho g\, dZ/dt = -(MP/RT)gv \tag{10}$$

to establish the relation between rate of change of pressure and rate of change of the absolute altitude Z. This relation between dP/dt and dZ/dt in the atmosphere depends entirely on the nature of the temperature distribution. On the assumption of the N.A.C.A. standard atmosphere the actual rate of climb dZ/dt is established for a given rate of change of pressure dP/dt at a given altitude Z and is proportional to the free air temperature T.

Consequently the sensitivity, which is the ratio of the pointer deflection θ of the indicator to the actual vertical speed v, is inversely proportional to the free air temperature T.

The component design factors of an uncompensated rate-of-climb meter were measured and are listed in Table 1. (This instrument will be referred to as Meter D hereafter.) The sensitivity calculated with the use of the components in Table 1 and according to Eq. (9) is shown by the solid line labeled S/S_0 in Fig. 2 as a function of altitude established from the temperature-altitude relation of the N.A.C.A. standard atmosphere. The expression of sensitivity by this ratio S/S_0 is equivalent to the defined sensitivity ratio F, as used in Eq. (3).

TABLE 1

Values of Component Design Factors of a Rate-of-Climb Meter*

V	=	216 cm.^{3}
A	=	6.0 cm.^{2}
C	=	12.8×10^{-9} cm.^{3}
k/A	=	8.83×10^4 dynes per cm. per cm.^{2}
D	=	82.5 rad. per cm.
c/A	=	0.26×10^4 gm. per sec. per cm.^{2}
E	=	323 cm. per sec. per rad.

* Meter D.

CHARACTERISTIC TIME AND CHARACTERISTIC DAMPING NUMBER

Since the climb indicators used in the present tests have greater than critical damping the differential equation relating the indicated vertical speed to actual vertical speed can be written in the form

$$\frac{d^2v_i}{dt^2} + \frac{n+1}{\tau}\frac{dv_i}{dt} + \frac{n}{\tau^2} v_i = \frac{n}{\tau^2} Fv \tag{11}$$

where

$$\tau = (b_1/b_0)\,(1 \pm \sqrt{1 - 4b_0/b_1^2})/2 \qquad (12)$$

$\cong b_1/b_0$ when b_1 is large compared to b_0 (or its equivalent b_0')

$$n = \left(\frac{b_1^2}{b_0} - 2\right)\frac{(1 \pm \sqrt{1 - 4b_0/(2b_0 - b_1^2)}}{2} \qquad (13)$$

$\cong (b_1^2/b_0) - 2$ when b_1 is large compared to b_0 (or its equivalent b_0'). Thus, in order to compute the characteristic time τ and the characteristic damping number n the coefficients b_1 and b_0 (or its equivalent b_0') must be considered under the conditions imposed for a particular case. Under any working condition the pressure P_2 in the capillary and the pressure P_1 in the chamber cannot be more than slightly different from the atmospheric pressure P. In an airplane cabin at constant temperature the temperature T_2 of the air in the capillary is the same as the temperature T_1 in the chamber. In this circumstance the first and third terms of b_1 vary with P and the second term is constant. The coefficient b_0 varies with P. Hence τ and n are functions of the pressure of the atmosphere and not of its temperature. The coefficient τ was calculated from the measured components of the system, including the design factors in Table 1. This is shown by the solid line in Fig. 2 as a function of altitude determined from the pressure-altitude relation of the N.A.C.A. standard atmosphere.

In an open cockpit T_2 may or may not be the same as T_1, according to the structure of the instrument.

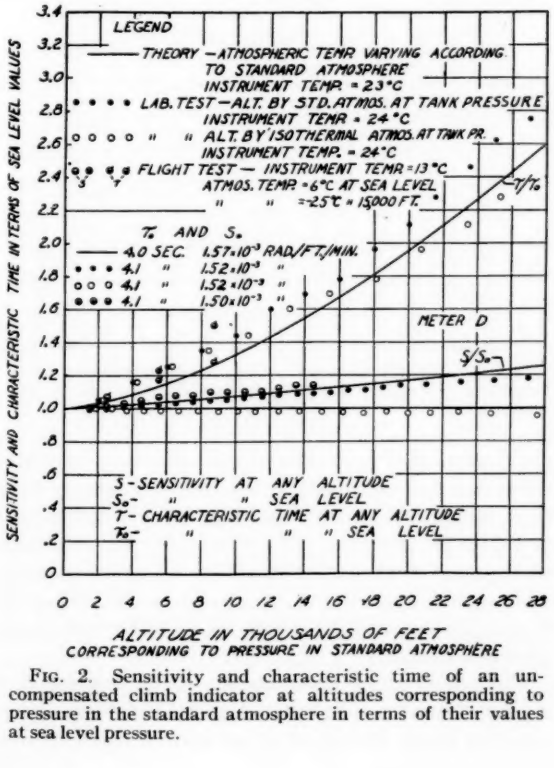
LEGEND
THEORY — ATMOSPHERIC TEMP VARYING ACCORDING TO STANDARD ATMOSPHERE INSTRUMENT TEMP. = 23°C
LAB. TEST — ALT. BY STD. ATMOS. AT TANK PRESSURE INSTRUMENT TEMP. = 24°C
" " ALT. BY ISOTHERMAL ATMOS. AT TANK PR. INSTRUMENT TEMP. = 24°C
FLIGHT TEST — INSTRUMENT TEMP. = 13°C ATMOS. TEMP. = 6°C AT SEA LEVEL
" " = -25°C " 15,000 FT.
T/T₀
T₀ AND S₀
4.0 SEC. 1.57×10⁻³ RAD/FT./MIN.
4.1 " 1.52×10⁻³ "
4.1 " 1.52×10⁻³ "
4.1 " 1.50×10⁻³ "
METER D
S/S₀
S - SENSITIVITY AT ANY ALTITUDE
S₀ - " " SEA LEVEL
T - CHARACTERISTIC TIME AT ANY ALTITUDE
T₀ - " " " SEA LEVEL
SENSITIVITY AND CHARACTERISTIC TIME IN TERMS OF SEA LEVEL VALUES
ALTITUDE IN THOUSANDS OF FEET CORRESPONDING TO PRESSURE IN STANDARD ATMOSPHERE

FIG. 2. Sensitivity and characteristic time of an uncompensated climb indicator at altitudes corresponding to pressure in the standard atmosphere in terms of their values at sea level pressure.

Since this case is not considered as important as the one for the heated cabin it is not treated here.

LABORATORY MEASUREMENT OF THE PERFORMANCE COEFFICIENTS

The values of S, τ, and n computed from the component parts of the instrument by the preceding described relations were checked against the measured coefficients of the assembled instrument. Table 2 shows a representative comparison of these coefficients at the pressure corresponding to 2000 ft. in the standard atmosphere. The only type of sensitivity test that

TABLE 2

Comparison of Measured and Calculated Performance Coefficients of a Rate-of-climb Meter* at a Pressure Equivalent to 2000 Ft. in the Standard Atmosphere and at an Instrument Temperature of 24°C.

Coefficient	S	n	τ
Name	Sensitivity $\frac{\text{radians}}{\text{ft. per min.}}$	Characteristic Damping Number	Characteristic Time
Dimensions		none	sec.
Value Measured from Complete Meter	1.55×10^{-3}	50** to 200	4.3
Value Calculated from Design Factors	1.61×10^{-3}	180† 170	4.2† 4.0

*Meter D.

**Wide range of estimate due to reading small differences between large numbers. For large values of n compared with unity the exact value is not important.

†Calculations of n and τ made from b_1 and two differently derived values of b_0.

can be performed on the climb indicator in the laboratory is to establish a pressure and a rate of change of pressure in a test chamber at a temperature corresponding to some given cabin temperature. The deflection of the pointer for a given rate of change of pressure depends only on the instrument temperature. In order to associate an altitude Z with the established pressure P and to associate a rate of change of altitude v with the established rate of change of pressure dP/dt, an assumption must be made with regard to the temperature distribution in the atmosphere. The time (in seconds) for a unit change in absolute altitude as determined by a standard altimeter will be the same in the laboratory and in the standard atmosphere for a unit pressure difference. With the use of these ideas a laboratory test can be made which will give the sensitivity variations in the atmosphere. Fig. 2 shows good agreement of theory, laboratory test, and flight test based on the standard atmosphere.

In an isothermal atmosphere the sensitivity according to theory and laboratory test (Fig. 2) would be constant for constant instrument temperature. For this reason an atmospheric temperature lapse rate less than the

standard will give a sensitivity less than in the standard atmosphere and for a larger lapse rate the sensitivity will be greater.

The characteristic time τ and the characteristic damping number n are determined in the laboratory from the response of the indicator to a sudden increase or decrease of rate of change of pressure, *e.g.*, sudden closing of the test tank leak valve by which rate of change of pressure is controlled. A plot of the logarithm of the meter reading as ordinate and time as abscissa is a straight line after a brief initial period and the reciprocal of the slope of this line is τ. The number n is the ratio of the ordinate of the extrapolated straight line at time $t = 0$ to the difference between this value and the original instrument reading at time $t = 0$. By this method of test the primary dynamic coefficient τ was found, at pressure corresponding to 2000 ft. in the standard atmosphere, to be 4.3 ± 0.1 seconds when recordings of instrument response were made with a movie camera and 4.3 ± 0.2 seconds when recordings were made from visual observations. In both cases the secondary coefficient n could be only estimated as lying between 50 to 200, due to the difficulty of reading small differences between large numbers on a plotted record. This apparently large discrepancy was of little importance, however, in the prediction of the dynamic characteristics of the meter, since for large values of n the exact value is immaterial. In this regard, consider the general equation

$$v_i = Ae^{-t/\tau} + Be^{-nt/\tau} + v_s \qquad (14)$$

which expresses the meter reading v_1 as a function of steady state response v_s and transient terms in which A and B are constants determined by initial conditions of the response motion. The term containing n soon vanishes in comparison with the other term for n greater than about 20. However, as n is decreased it becomes more accurately calculable and has an increasing effect on the response.

Fig. 2 shows the agreement of results of theory, laboratory test, and flight test of τ based on the standard atmosphere. The laboratory and flight test results were taken from visual observations.

Flight Tests

The final test of any theory is whether it agrees reasonably well with actual results under working conditions. In this case, the calculated performance of a climb indicator was subjected to comparison with flight tests. The climb indicator and an altimeter having negligible dynamic errors were mounted in a cork-lined, glass-front box that was held at constant temperature ±0.5°C. by the heat of two small electric light bulbs.

The sensitivity test was made by timing with a stop watch the intervals between changes of 500 ft. in indicated altitude while the indicated rate of ascent was 850 ± 50 ft. per min. from a height of 2000 ft. to 10,500 ft. and while the indicated climb was 400 ± 50 ft. per min. from 11,000 ft. to 14,500 ft. Similarly, an indicated rate of descent of 1000 ± 50 ft. per min. was maintained from 15,000 ft. down to 500 ft. Atmospheric temperature readings were made and were found to be from 2° to 10°C. lower than the standard. Adjustments were made for variations in indicated climb and temperature. Reasonably good agreement of flight results with theory and laboratory test is shown by the sensitivity curve labeled S/S_0 in Fig. 2.

Another kind of flight test was made to determine the characteristic time of the instrument and to show what significance it has as a criterion of performance under conditions of changing rate of climb. The airplane was maneuvered as fast as practicable from level flight to constant rate of climb. During the maneuver two observers read and recorded rate of climb, altitude, and time as often as possible. The interval was three to four seconds. From these data the plots in Figs. 3, 4, and 5 were made. The plotted data were analyzed by

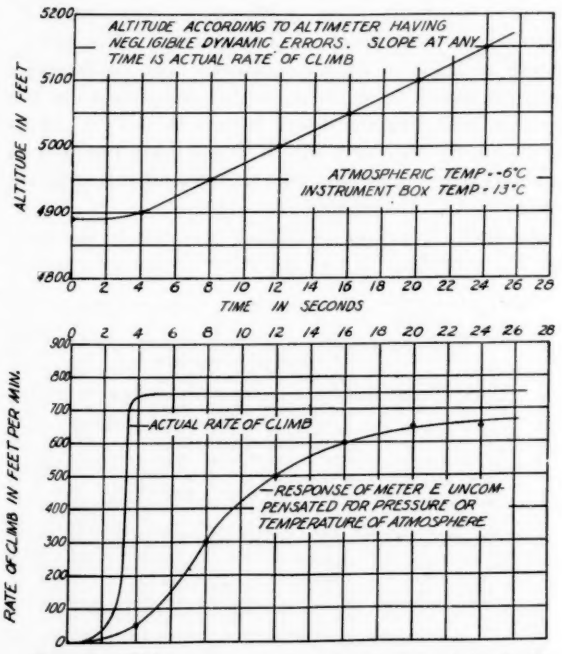

Fig. 3. Flight response of an uncompensated climb indicator to sudden change from level flight to 750 ft. per min. ascent.

the same method as used for similar laboratory tests and τ was found to be calculable with less consistency than from laboratory results. See Fig. 2 for a comparison of values for Meter D. However, even the maximum discrepancy of 15 percent based on the actual value of τ at an altitude of 8700 ft. amounts to a time difference of only 0.6 sec. and the points are on either side of the laboratory value.

Figs. 3, 4, and 5 show the lag of the reading of a representative uncompensated climb indicator (designated as Meter E) behind actual vertical speed for sud-

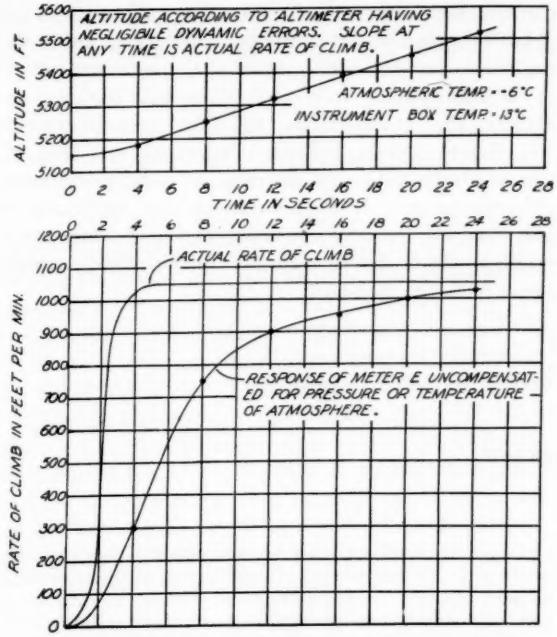
ALTITUDE ACCORDING TO ALTIMETER HAVING NEGLIGIBLE DYNAMIC ERRORS. SLOPE AT ANY TIME IS ACTUAL RATE OF CLIMB.
ATMOSPHERIC TEMP. -6°C
INSTRUMENT BOX TEMP. 13°C
ALTITUDE IN FT.
TIME IN SECONDS
ACTUAL RATE OF CLIMB
RESPONSE OF METER E UNCOMPENSATED FOR PRESSURE OR TEMPERATURE OF ATMOSPHERE.
RATE OF CLIMB IN FEET PER MIN.

FIG. 4. Flight response of an uncompensated climb indicator to sudden change from level flight to 1050 ft. per min. ascent.

den changes from level flight to rates of climb of 750, 1050, and 2150 ft. per min. The shapes of the plotted curves are similar, and after adjustment is made for slight variations in the time for the airplane to attain level flight in each case, non-dimensional plots of the curves are as nearly identical as might be expected from flight data. For such a comparison see Fig. 6.

From curves such as these the time in seconds can be determined for the error in reading after a sudden change to come within some allowable value, say 10 percent. This specification is similar to one required of climb indicators at present. However, a consideration of the characteristic time is important because an inspection of the equation expressing τ in terms of the component parts of the instrument can indicate which factors should be changed to get a desired result—or whether such a result is possible.

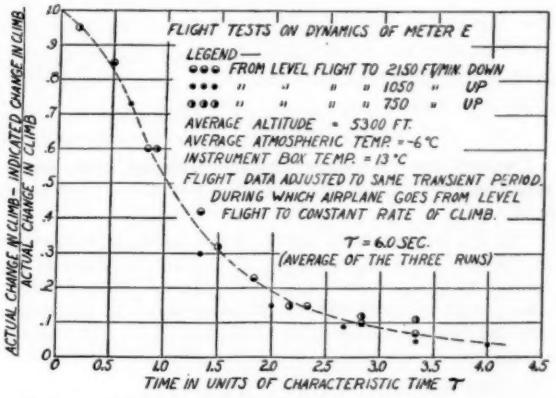
FLIGHT TESTS ON DYNAMICS OF METER E
LEGEND—
FROM LEVEL FLIGHT TO 2150 FT/MIN DOWN
" " " " 1050 " UP
" " " " 750 " UP
AVERAGE ALTITUDE = 5300 FT.
AVERAGE ATMOSPHERIC TEMP. = -6°C
INSTRUMENT BOX TEMP. = 13°C
FLIGHT DATA ADJUSTED TO SAME TRANSIENT PERIOD DURING WHICH AIRPLANE GOES FROM LEVEL FLIGHT TO CONSTANT RATE OF CLIMB.
τ = 6.0 SEC. (AVERAGE OF THE THREE RUNS)
ACTUAL CHANGE IN CLIMB - INDICATED CHANGE IN CLIMB / ACTUAL CHANGE IN CLIMB
TIME IN UNITS OF CHARACTERISTIC TIME τ

FIG. 6. Non-dimensional comparison of flight responses of an uncompensated climb indicator to changes from level flight to three rates of climb.

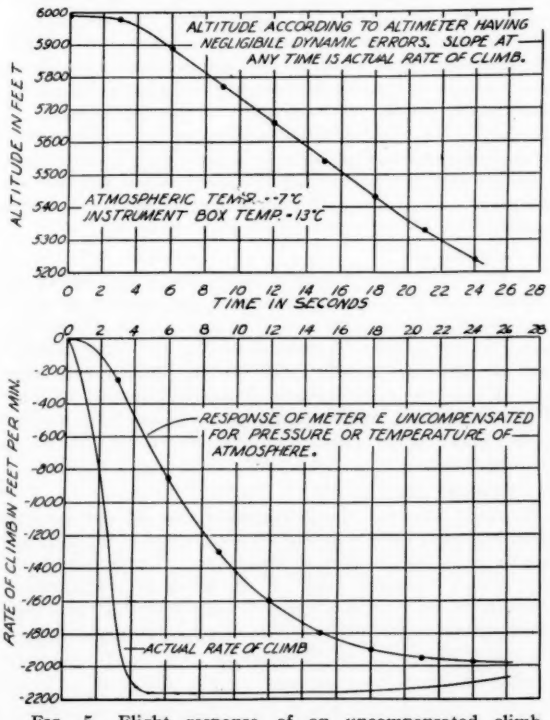
ALTITUDE ACCORDING TO ALTIMETER HAVING NEGLIGIBLE DYNAMIC ERRORS. SLOPE AT ANY TIME IS ACTUAL RATE OF CLIMB.
ATMOSPHERIC TEMP. -7°C
INSTRUMENT BOX TEMP. 13°C
ALTITUDE IN FEET
TIME IN SECONDS
RESPONSE OF METER E UNCOMPENSATED FOR PRESSURE OR TEMPERATURE OF ATMOSPHERE.
ACTUAL RATE OF CLIMB
RATE OF CLIMB IN FEET PER MIN.

FIG. 5. Flight response of an uncompensated climb indicator to sudden change from level flight to 2150 ft. per min. descent.

DISCUSSION

The information acquired by this investigation can be applied to the performance study of an uncompensated rate-of-climb indicator under the three conditions of (1) level flight, (2) sudden change from level flight to constant rate of climb, and (3) steady climb.

The conclusions pertaining to level flight are based on the results shown in Fig. 6, since level flight is related to changes from level flight to constant rate of climb. In the case of flight along a constant pressure level followed by loss of altitude at a constant rate, the question arises as to whether a sensitive altimeter or a climb indicator will give the first indication of the change. On the basis of comparison of equal minimum perceptible angular deflections of the sensitive altimeter and of the climb indicator from which the data were observed for Fig. 6, it is concluded that this climb indicator will attain the minimum perceptible reading before the altimeter, except for very small true rates of climb. However, as a result of the increase in "lag" as measured by τ and as shown in Fig. 2, this reliability is decreased with altitude.

In the case of a deliberate change from level flight to a desired constant vertical speed, the pilot wishes to know how long he must wait before the error in meter reading will be within some allowable value, say 10 percent.

If he were using a meter similar to the one for which data are given in Fig. 6 he should wait at least 16 seconds to get an accurate reading of vertical speed at an altitude of 5300 ft. and should wait 20 seconds at 12,000 ft. (the latter statement being based on a laboratory experiment). The time required for a definite indication of 100 ft. per min. at an altitude of 5300 ft. would occur after an interval of 2 seconds for a true rate of climb of 2000 ft. per min. and after an interval of 6 seconds for a true rate of climb of 200 ft. per min.

Sensitivity of a particular uncompensated rate-of-climb meter can vary from calibration value only as the result of a change of the temperature of the air in the capillary or as the consequence of the assumed nature of the atmosphere. In a cabin of constant temperature equal to that of calibration, the only source of error in the relation between indicated and actual rate of climb can be attributed to the distribution of temperature in the atmosphere. If the instrument were calibrated to the standard, the only remaining source of atmospheric errors would be due to variations of the existing atmosphere from the standard.

Book Review

Jahrbuch der Deutschen Luftfahrtforschung, 1938, Ergänzungsband; R. Oldenbourg, München and Berlin; 403 pages, R.M. 18.

This is a supplementary volume of the *Jahrbuch der Deutschen Luftfahrtforschung*, and contains the papers presented at the Annual Meeting of the *Lilienthal-Gesellschaft für Luftfahrtforschung*, held in Berlin, October 12 to 15, 1938. In this review only the topical headings of the individual papers will be given, arranged in the following groups.

(1) General Lectures

This group consists of the main lectures of general interest. Increase of aircraft speed in recent years was the subject of the first paper by *E. Heinkel* (Rostock), who presented a clear picture of the individual factors contributing to airplane speed together with the future outlook for further speed increase. *I. Sikorsky* (Bridgeport, Conn., U.S.A.) discussed the present state of the large flying boat, with particular reference to its advantages for trans-oceanic travel. The subject of *A. Fedden's* (Bristol, England) paper was the development of the mono-sleeve valve for aero engines. *C. von Gablenz* (Deutsche Lufthansa) discussed operation experiences in aerial transport and their consequences for development and research.

(2) Special Subjects

W. Hahnemann (Berlin) gave a comprehensive view of the physical principles underlying various electrical and acoustical methods in use as navigation aids in blind flying. *D. Tomlinson* (T.W.A., U.S.A.) presented a paper on high altitude flying observations and economic calculations. Icing was the subject of two papers, one by *W. Findeisen* (Friedrichshafen), who considered meteorological and physical atmospheric conditions prerequisite for icing; the other by *L. Ritz* (Göttingen) who gave experimental results concerning the effects of icing on airplane parts, especially wings. *A. Ferri* (Guidonia, Italy) described recent work of the supersonic wind tunnel at Guidonia.

(3) Airplane Construction

C. Minelli (Venice, Italy) discussed application of the energy method to the static analysis of airplane structures. *F. Bollenrath* (D.V.L.) gave results of recent work concerning endurance strength and aging of aircraft materials. *O. Nissen* (Dessau) presented a paper on modern aircraft strength problems, with particular emphasis on vibration and repeated stresses. The paper of *W. Perring* (R.A.E., England) was on recent airscrew research in Great Britain, with special reference to the take-off problem. Aerodynamic principles of automatic stabilizers was the subject of a talk by *F. Haus* (Brussels, Belgium). *H. Kaul* (D.V.L.) discussed statistical considerations of operating stresses in airplane wings.

(4) Airplane Motors

In this group, *H. Sachse* (München) talked on various methods of automatic regulation of airplane motors. Investigations concerning the high altitude behavior of airplane engines, made in the Fiat laboratories, were described by *P. Ragazzi* (Turin, Italy). *J. Ellor* (Derby, England) discussed several problems of supercharging in aero engines. *L. Poincaré* (Paris, France) gave results of engine power measurements in flight. *E. Schmidt* (Braunschweig) gave a talk on graphical methods of calculating work cycles of internal combustion engines, taking into consideration the dependence on temperature of the specific heats. *F. Schmidt* (D.V.L.) discussed possibilities for decreasing thermodynamic and mechanical losses in airplane engines, with corresponding improvement in regard to power output and fuel consumption. *M. Christian* (Berlin) talked on air-cooled, V-type engines.

(5) Equipment

A. Esau (Jena) gave a comprehensive view of the physical and technical aspects of centimeter waves. Automatic control systems for airplanes was the subject of papers by *E. Fischel* (Siemens, Berlin), *G. Klein* (Siemens, Berlin), and *K. Wilde* (Askania, Berlin). *W. Crone* and *H. Klumb* (D.V.L.) discussed the origin and elimination of electrostatic charges on aircraft in flight. *P. Kotowski* and *H. Spiller* (Berlin) gave a paper on the design of radio receiver input circuits with reference to the external disturbance level.

(6) Hydrodynamics

In this final group, representatives of four different countries described latest equipment and research results of the large towing basins of their respective laboratories. The lecturers were: *C. Cremona* (Guidonia, Italy), *H. Garner* (R.A.F., England), *S. Truscott* (N.A.C.A., U.S.A.), and *W. Sottorf* (D.V.L., Germany).

FRANK L. WATTENDORF

A Correction to the Yawing Moment Due to Ailerons for Circular Wind Tunnels

H. J. STEWART

California Institute of Technology

THE yawing effects of the unsymmetrical vortex system caused by deflected ailerons are known to be modified by the presence of wind-tunnel walls. This modification has been calculated by Koning and van der Maas[1] for the case of a single aileron extending to the tip of the wing. The present calculation differs from that of Koning and van der Maas in the following respects: (1) The ailerons may be set in from the tips. (2) The modification for the case where two ailerons are deflected is determined. (3) Suitable non-dimensional parameters are found by means of which the results can be presented in an easily useable form.

The following symbols are used:

$\Gamma = \Gamma' + \Gamma'' =$ total circulation around the wing
$\Gamma' =$ symmetric circulation (elliptic)
$\Gamma_0 =$ strength of circulation at center of wing
$\Gamma'' =$ aileron circulation
$\Gamma_R =$ strength of aileron horseshoe vortex which replaces Γ''
$w = w' + w'' =$ downwash at wing due to tunnel walls
$w' =$ downwash due to images of elliptic lift system
$w'' =$ downwash due to images of aileron lift system
$U =$ wind velocity
$S =$ wing area
$b =$ wing span
$r =$ tunnel radius
$a_1 =$ distance from wing centerline to inner tip of aileron
$a_2 =$ distance from wing centerline to outer tip of aileron
$C_L =$ lift coefficient
$C_r =$ rolling-moment coefficient
$\Delta\alpha =$ tunnel wall correction to angle of attack
$\Delta C_y =$ tunnel wall correction to yawing-moment coefficient
$x =$ distance along span positive to right

In these calculations three assumptions are made. First, it is assumed that, in computing the induced velocities at the wing caused by the wind-tunnel walls, the unsymmetrical vortex system produced by the ailerons can be replaced by horseshoe vortices whose spans are the spans of the ailerons and whose strengths are those required to produce the wind-tunnel rolling moment. Second, it is assumed that the wing can be represented as the sum of the aileron system described above and an elliptic circulation distribution which would give the same total lift as the actual wing. Third, it is assumed that the vortex sheet leaving the wing extends back to infinity with no change. The first two assumptions express conditions very well, as long as the wing tip is not too close to the tunnel wall, and are probably valid as long as the span of the model is less than nine-tenths of the tunnel diameter, at least for closed working sections. The third assumption will be discussed later. With these assumptions the vortex system of a wing with the right aileron deflected in a closed working section is as shown in Fig. 1.

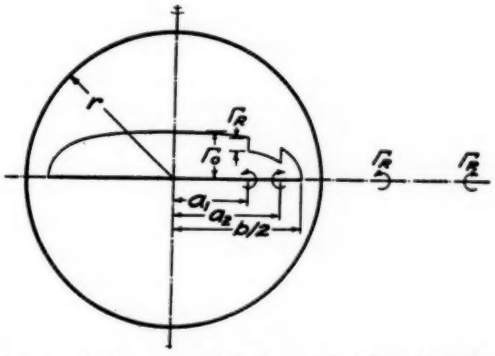

FIG. 1. Vortex system for wing with right aileron deflected.

In accordance with the Prandtl three-dimensional wing theory, the yawing-moment correction is

$$\Delta C_y = \frac{2}{U^2 S b}\int_{b/2}^{b/2} W x \Gamma dx$$

In this case the induced downwash, w, has two components, w' and w''. Similarly, the circulation, Γ, has two components, Γ' and Γ''. The product $w\Gamma$ thus has four parts; *i.e.*,

$$w\Gamma = w'\Gamma'' + w''\Gamma' + w''\Gamma'' + w'\Gamma'$$

The effect of each of these parts will be found separately. The first will be called ΔC_{y_1}, the second ΔC_{y_2}, and the third ΔC_{y_3}. The fourth obviously has no effect, as the integrand is an odd function. To calculate the respective terms the circulations and downwash velocities must first be calculated in terms of the dimensionless coefficients C_r and C_L.

Now

$$C_r = \frac{-2}{USb}\int_{-b/2}^{b/2} x\Gamma'' dx$$

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or, since $\Gamma'' = \Gamma_R =$ constant, by the first assumption above,

$$\Gamma_R = C_r \frac{USb}{a_2^2 - a_1^2}$$

The corresponding downwash velocity, w'', is

$$w'' = \Gamma_R r^2(a_2 - a_1)/4\pi(r^2 - a_1x)(r^2 - a_2x)$$

Similarly,

$$C_L = \frac{2}{US}\int_{-b/2}^{b/2} \Gamma' dx$$

or, since $\Gamma' = \Gamma_0\sqrt{1 - (2x/b)^2}$, in accordance with the assumption of elliptic basic lift distribution,

$$\Gamma_0 = C_L \frac{2US}{\pi b}$$

The downwash at the wing due to the image vortices of the elliptic lift distribution, w', is

$$w' = \frac{\Gamma_0}{b\pi}\int_{-b/2}^{b/2} \frac{\xi^2 d\xi}{(x\xi - r^2)\sqrt{b^2 - 4\xi^2}}$$

$$= \frac{\Gamma_0 r^2}{2b}\left\{\frac{1}{x^2} - \frac{2r^2}{x^2\sqrt{4r^4 - b^2x^2}}\right\}$$

Using these results, ΔC_{y_1} can be calculated as follows:

$$\Delta C_{y_1} = \frac{-\Gamma_0\Gamma_R r^2}{U^2Sb^2}\int_{a_2}^{a_1}\left\{1 - \frac{2r^2}{\sqrt{4r^4 - b^2x^2}}\right\}\frac{dx}{x}$$

or

$$\Delta C_{y_1} = C_r C_L \frac{Sr^2}{b^2(a_2^2 - a_1^2)}\left\{F_1\left(\frac{ba_2}{2r^2}\right) - F_1\left(\frac{ba_1}{2r^2}\right)\right\}$$

where

$$F_1(x) = -(2/\pi)\log_e\left[1 + \sqrt{1-x^2}\right]$$

The function $F_1(x)$ is plotted in Fig. 2.

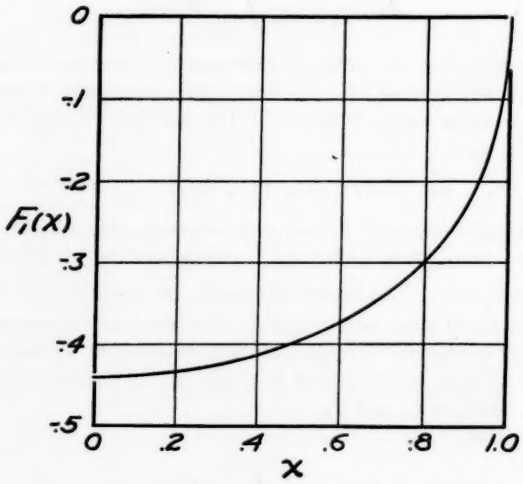

FIG. 2. Correction function for ΔC_{y_1}.

If the variation of w' over the span is neglected, a very simple approximate expression for ΔC_{y_1} can be obtained.

$$\Delta C_{y_1} = \frac{w'\,2}{U\;USb}\int_{-b/2}^{b/2}\Gamma'' x dx$$

$$= -C_r w'/U = C_r\Delta\alpha$$

where $\Delta\alpha$ is the correction to the angle of attack, in radians, to take into account the wind-tunnel wall effect. This approximate equation has been used to correct wind-tunnel yawing moments by Platt and Shortal.[2] It gives values about 10 percent less than the more accurate expression obtained above.

In a similar fashion ΔC_{y_2} can be calculated.

$$\Delta C_{y_2} = \frac{\Gamma_0\Gamma_R}{2\pi U^2 S}\int_{-b/2}^{b/2} x\sqrt{b^2 - 4x^2}\,\frac{r^2(a_2 - a_1)\,dx}{(r^2 - a_1x)(r^2 - a_2x)}$$

or

$$\Delta C_{y_2} = C_r C_L \frac{S}{a_2^2 - a_1^2}\left\{F_2\left(\frac{a_2}{2r^2}\right) - F_2\left(\frac{ba_1}{2r^2}\right)\right\}$$

where

$$F_2(x) = \left(1 - \sqrt{1 - x^2}\right)/2\pi x^2$$

The function $F_2(x)$ is plotted in Fig. 3.

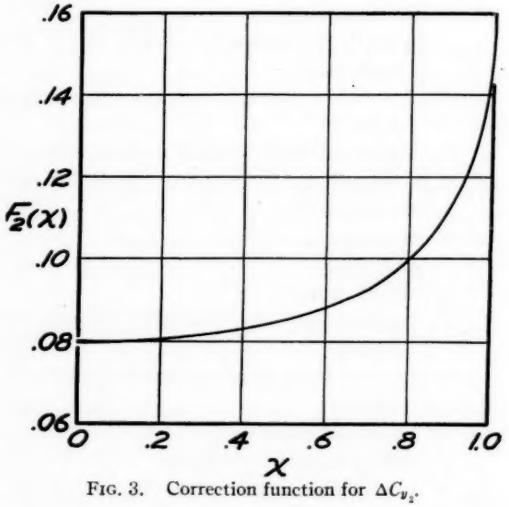

FIG. 3. Correction function for ΔC_{y_2}.

The calculations for ΔC_{y_3} are as follows:

$$\Delta C_{y_3} = \frac{-\Gamma_R^2}{2\pi U^2 Sb}\int_{a_1}^{a_2}\frac{r^2(a_2 - a_1)\,xdx}{(r^2 - a_1x)(r^2 - a_2x)}$$

or

$$\Delta C_{y_3} = -C_r^2\frac{Sbr}{2\pi(a_2^2 - a_1^2)^2}F_3\left(\frac{a_2}{r}, \frac{a_1}{a_2}\right)$$

where

$$F_3(x,y) = \frac{1}{xy}\log_e\frac{1 - x^2y}{1 - x^2y^2} - \frac{1}{x}\log_e\frac{1 - x^2}{1 - x^2y}$$

The function $F_3(x,y)$ is shown in Fig. 4.

These corrections have been calculated assuming the right aileron to be deflected. For left aileron deflec-

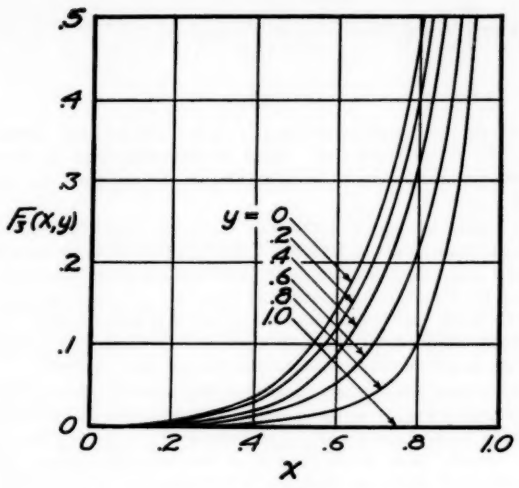

FIG. 4. Correction function for ΔC_{y_3}.

tions, ΔC_{y_1} and ΔC_{y_2} are unchanged, but the sign of ΔC_{y_3} is changed.

As ΔC_{y_1} and ΔC_{y_2} are linear in C_r, these corrections can be obtained when both ailerons are deflected by using the rolling-moment coefficient due to both ailerons; *i.e.*, the equations for the corrections are not changed. ΔC_{y_3} is quadratic in C_r, so that this effect is quite different when two ailerons are deflected. The yawing moment due to the left aileron's circulation and to the image system of the right aileron can quite readily be shown to cancel the moment due to the image system of the left aileron and the right aileron's circulation. As a result of this, ΔC_{y_3}, for the case when both ailerons are deflected, is given by the formula

$$\Delta C_{y_3} = \left\{C_{r_l}{}^2 - C_{r_r}{}^2\right\} \frac{Sbr}{2\pi(a_2{}^2 - a_1{}^2)^2} F_3\left(\frac{a_2}{r}, \frac{a_1}{a_2}\right)$$

As ailerons are normally deflected so that C_{r_l} and C_{r_r} are about equal, ΔC_{y_3} may be considered to vanish when both ailerons are deflected.

The total correction, $\Delta C_y = \Delta C_{y_1} + \Delta C_{y_2} + \Delta C_{y_3}$, must be subtracted for a closed wind tunnel and added for an open jet wind tunnel. The importance of this correction may be shown by a sample calculation. Suppose the left aileron of a model is deflected, and the following data are chosen:

$r = 5$ ft.	$S = 8$ sq.ft.
$b = 8$ ft.	$C_L = 1.50$
$a_2 = 3\frac{1}{2}$ ft.	$C_r = 0.0300$
$a_1 = 2$ ft.	

Then

$$\Delta C_{y_1} = 0.00069;\ \Delta C_{y_2} = 0.00024;\ \Delta C_{y_3} = 0.00008;$$
$$\Delta C_y = 0.00101$$

The total correction is likely to be a large percentage of the uncorrected yawing-moment coefficient; in fact it is sometimes larger than the uncorrected yawing-moment coefficient for models as large as this ($b/r = 1.6$).

In this example ΔC_{y_3} is small when compared with the sum of the other two. This is a general result except when either the rolling moment or the span is so large that the basic assumptions break down, or when the wing is near zero lift. Hence ΔC_{y_3} can ordinarily be neglected.

It should be noted that yawing moments produced by frictional forces are practically unaffected by the presence of the tunnel walls, and that yawing moments produced by vortex systems not inductively coupled to the wing, such as the yawing moment produced by the vertical tail, have corrections that are proportional to the velocities induced by their own image systems. As in most cases, only the images of the wing vortex system cause large induced velocities, yawing moments due to anything except the ailerons have, in general, negligible corrections for the effect of the wind-tunnel walls.

As was mentioned before, the corrections were calculated assuming that the vortex sheet in back of the wing does not roll up. It is known that the vortex sheet does roll up only a few chord lengths behind the wing, so that the image system representing the tunnel walls should be changed to take this into account. It is apparent that the effect of this on w' and ΔC_{y_1} is small; however, as the sheet rolls up, the horseshoe aileron vortex is, in effect, ended only a short distance behind the wing, and w'' is much reduced. A preliminary calculation shows that the decrease in ΔC_{y_2} and ΔC_{y_3}, due to this effect, might be large enough to decrease the total correction by about 15 percent. This effect would also decrease the wind-tunnel wall correction to the rolling-moment coefficient, as calculated by Koning and van der Maas[1] or Biot[3] in a slightly greater ratio. As there is no apparent way in which this "rolling up" effect can be deduced theoretically, experimental work has been started in order to investigate its importance and magnitude.

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[1] Koning, C., and van der Maas, H. J., *De tunnelwandcorrectie op rol- en giermomenten voor een model met asymmetrische liftverdeeling*, Verslagen en Verhandelingen van den Rijks-Studiedienst voor de Luchtvaart Amsterdam, Deel IV, pages 240–255, 1927.

[2] Platt, Robert C., and Shortal, Joseph A., *Wind-Tunnel Investigation of Wings with Ordinary Ailerons and Full-Span External-Airfoil Flaps*, N.A.C.A. Technical Report, No. 603, 1937.

[3] Biot, M., *Korrektur für das Quermoment von Tragflügeln bei Untersuchungen im Windkanal mit Kreisquerschnitt*, Zeitschrift für Flugtechnik und Motorluftschiffahrt, Vol. 24, No. 15, pages 410 and 411, 1933.

Book Review

Modern Developments in Fluid Dynamics, Vols. I and II, by the Fluid Mechanics Panel of the British A.R.C., and collaborators; edited by S. GOLDSTEIN; Oxford University Press, London and New York, 1939; 680 pages, $16.00.

The great advances made in the investigations of fluid mechanics in the past decade have created a demand for a comprehensive and authoritative work such as this set represents. It was composed by the Fluid Mechanics Panel of the British A.R.C., consisting of L. Bairstow, A. Fage, S. Goldstein, B. M. Jones, A. R. Low, E. Ower, E. F. Relf, L. F. G. Simmons, R. V. Southwell, H. B. Squire, and G. I. Taylor, with the collaboration of V. M. Faulkner, L. Howarth, L. Rosenhead, and H. C. H. Townsend. The selection and general arrangement of the subject matter is a tribute to the Editor, Dr. S. Goldstein.

Judging from the formidable list of authors one might expect an elegant treatise directed toward the relatively few experts in this field. Its elegance cannot be disputed, but the thorough—almost leisurely—treatment of those phases of the subject of primary interest in aeronautics foreshadows a wide appeal among those interested in the physical and engineering aspects of fluid flow.

The subject matter is not concerned with the potential flow of inviscid fluids or with the vortex theory of airfoils, except to summarize the results of work recorded in other books, nor does it discuss problems of compressibility; it deals with the laminar and turbulent flow of viscous fluids in boundary layers, wakes, and wind tunnels, and with transfer of heat in laminar and turbulent flow. Modern theories, as well as all of the available pertinent experimental data, are given and fully discussed. While technical applications are not specifically treated, the results are in a form which permits of their easy application to technical problems.

Chapters I and II are devoted to introductions to Fluid Mechanics and to boundary layers, respectively. Qualitative and semi-quantitative discussions of viscosity, non-dimensional parameters, flow in tubes, vorticity and circulation, laminar and turbulent flow in boundary layers, and about bodies of various shapes, along with the results of illustrative experiments, are given. A profusion of photographs showing the fundamental character of the flow, both steady and unsteady, about airfoils and other shapes permit a clear visualization of the flow mechanism under various conditions.

After almost a hundred pages of this introductory material, Chapter III takes up the equations of viscous fluid flow. The chapter begins with a brief résumé of the mathematical equations governing the motion of a viscous incompressible fluid. Both vector and Cartesian notations are used. There follow examples of exact solutions of the equations of motion. Though the explanations are adequate and the mathematical analyses sufficiently detailed, the inclusion of explanatory diagrams would have improved the clarity of the derivations.

Chapter IV on "The Mathematical Theory of Motion in a Boundary Layer" deals with the derivation of the boundary layer equations and with solutions of problems in laminar flow. The momentum equations are considered in detail. A great deal of space is devoted to rather complete expositions of the various analyses of the separation of the laminar boundary layer. The chapter closes with solutions to some problems of unsteady flow in boundary layers.

The concept of turbulence is introduced in Chapter V. Derivation of the stresses in turbulent flow and a discussion of correlation lead up to a short review of the literature on stability of laminar flow between rotating cylinders and along flat plates. There follows a discussion of isotropic turbulence and the statistical, mixture length, momentum transfer, and vorticity transfer theories of turbulent flow. Scale of turbulence and its decay behind grids along with experimental results are treated in detail.

Chapter VI on "Experimental Apparatus and Methods of Measurement" gives very brief descriptions of wind tunnels, water tanks, and whirling arms, and some of their characteristics, instruments for measuring pressure and velocity, and methods for visualization and photography of fluid motion. The latter section will be particularly useful giving as it does so many of the details of the experimental arrangements required.

Flow in pipes, channels, and along flat plates, in both theory and experiment, are taken up in detail in Chapters VII and VIII (the latter is the first chapter of Volume II). The first section, on laminar flow treats growth of the boundary layer, inlet length, and effects of roughness and curvature. The transition from laminar to turbulent flow is considered in the second section. The factors affecting transition and some of the phenomena associated with it are described. The third section (Chapter VIII) is devoted to turbulent flow. Theoretical velocity distributions and resistance calculations are checked with experiment.

The flow about symmetrical and asymmetrical cylinders (airfoils) forms the subject matter of the next two chapters. By far the greater amount of space is concerned with experimental results on pressure distributions, streamlines, lift, drag and skin friction measurements, and the effects of roughness, Reynolds Number, turbulence, and protuberances on the surface. The effect of finite aspect ratio on the drag and the characteristics of a flapped airfoil are considered briefly.

The next chapter is devoted to the flow about spheres and solids of revolution. The flow about a sphere and its use as a turbulence meter are taken up in detail. The second section concerns measurements on airship shapes and agreement with theory. The theories are discussed but mathematical analyses are omitted.

There follows a chapter on Boundary Layer Control, in which the various experimental results, dealing largely with the sucking away of the boundary layer on the upper surface of airfoils, are given and discussed.

The wakes behind bodies are treated in the next chapter. Fairly complete derivations and discussions of theory and their experimental verifications are given. The turbulent spreading of jets is considered in detail.

The last two chapters are concerned with heat transfer in laminar and turbulent flow. These are remarkably complete and detailed theoretical calculations are carried out. The various theories of turbulent flow are compared on the basis of how closely they predict the temperature distribution in the wakes of rods and figures of revolution.

The book closes with an interesting historical note on the development of the currently accepted idea that the fluid immediately in contact with the surface of a solid body can be considered as having no velocity relative to the surface.

The many references to the literature represent a valuable part of the work. In addition to those given in the text there is a list of references to collected works and to papers on allied topics at the end of each chapter.

The engineer not well acquainted with the theoretical aspects of Fluid Mechanics will nevertheless find much valuable material, since so much of the text deals with discussions of experimental results. The authors deserve the highest commendation for making available a set that will undoubtedly be the standard work on the subject for many years to come.

A. M. KUETHE

Vibration of Radial Aircraft Engines, Part II*

G. P. BENTLEY

Sperry Gyroscope Company

Free Engine Vibration and Experimental Results

Vibration forcing functions acting on the engine frame must have, at any instant of time, complete equal and opposite reactions. These reactions will be provided by inertia and elastic forces set up by vibration of the engine and its mounting structure. In general, as the mechanical restraints of the mounting structure are reduced, the ratio of inertia reactions to elastic reactions will increase. If the restraints are sufficiently decreased, the engine will be vibration "isolated" and practically the entire forcing function reaction will be due to the inertia reactions of the motion of the engine crankcase and its directly associated structure. The "directly associated structure" includes the propeller and its gyroscopic effects.

The Isolating Structure

An aircraft engine has six possible different motions in space. The three linear and three angular motions may be made independently or in any combination and are termed "degrees of freedom." To properly isolate an engine not only must the elastic restraints be low, but they must be so arranged that there is no coupling between the various degrees of freedom. In other words, vibration in one degree of freedom must not cause alternating forces or couples in another degree of freedom.

The type of engine isolation structure developed for engine vibration tests to fulfill these isolation requirements is shown schematically in Fig. 4 and the actual structure is reproduced in Figs. 5 and 6. This structure was intended for test purposes only, and should not be construed to be directly applicable to aircraft use.† The engine mass was suspended by springs parallel to the three engine axes, so arranged that the elastic reactions were symmetrical with respect to the center of gravity of the isolated mass. To prevent persistence of any large amplitude natural frequency oscillations of the isolated mass which might be excited by transient forces or couples, friction damping was introduced into the suspension by spring-loaded plugs. Friction forces acting on the engine due to this damping arrangement were small compared to the engine inertia reactions for all but the very low frequency motions of the engine frame and so may normally be neglected.

Vibration of Isolated Engine in Translation

If a forcing function acts on the engine along a particular axis there will be at any instant an equilibrium of forces at the center of gravity and along that axis which may be expressed in the form:

$$\text{inertia force} + \text{damping force} + \text{elastic force} = \text{forcing function} \qquad (1)$$

Elastic and damping forces depend on the strength of the mount springs and the magnitude of the friction damping forces. The inertia reaction is furnished by the engine motion and is equal to the time rate of change of momentum of the suspended mass along the axis under consideration.

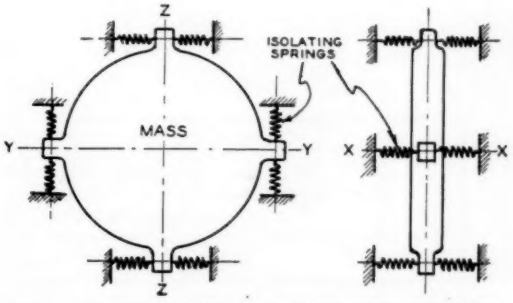


Fig. 4. Schematic vibration isolating engine suspension.

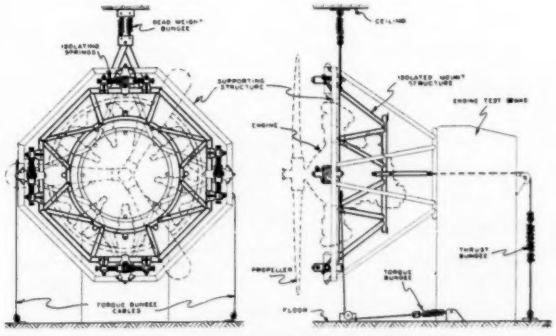


Fig. 5. Drawing of M.I.T. vibration isolating mount for test stand vibration studies.

Presented at the Power Plants Session, Seventh Annual Meeting, I. Ae. S., January 26, 1939.

*Part I of this paper, on "Theoretical Forcing Functions" appeared in the May issue of the Journal. References 1 through 8 were included in Part I.

† This mount design was due to E. S. Taylor and C. S. Draper. An isolating engine mount having similar characteristics, but suitable for flight work, is described in reference 9.

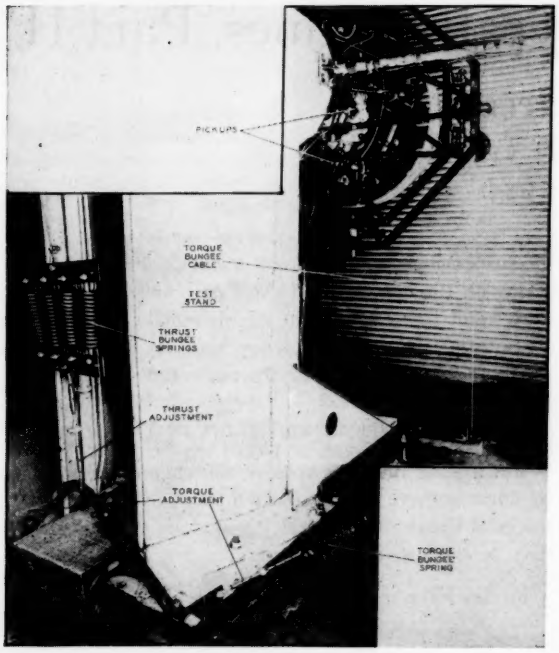


FIG. 6. Composite photograph of flexible engine mount installation showing thrust and torque bungees.

Engine forcing functions along the engine axes have been presented in Part I of this paper. All inertia forces include the factor ω^2 and since $\omega = 2\pi f$ (f = engine speed in revolutions per second) the forcing functions may be rewritten in the form

$$F_x = \Sigma_n [a_{nx} f^2 \sin n\theta + b_{nx} f^2 \cos n\theta] \qquad (2)$$

for the X axis, and similarly for the other axes.

The torque required to drive a fixed pitch aircraft propeller is approximately $T = (\text{constant}) \cdot \omega^2$. Gas pressure torque must consequently be proportional to the square of the engine speed; exhaust gas reactions may also be assumed to vary as ω^2. Harmonic analyses of torque curves at various throttle settings show that harmonic amplitudes of gas pressure forcing functions are approximately a constant fraction of the mean torque, regardless of throttle setting. The forcing functions due to gas pressure in an engine under propeller load may, therefore, be included in the coefficients of Eq. (2).

Substitution of the proper mathematical terms in Eq. (1) produces the equation of motion for the engine along the various axes. Solution of the equations of motion for the three engine axes results in the relatively simple expressions of Plate V. Once the various coefficients a and b have been determined, substitution in formulae of Plate V gives the theoretical engine vibration both in magnitude and phase. Strictly, these relations are true only for forcing frequencies high compared to the natural mount frequency in the degree of freedom in question. For frequencies near the mount frequency ω_n a multiplying factor M must be applied dependent on the ratio of forcing frequency $n\omega$ to ω_n.[10] This correction factor is included in the plot of Plate V. There is also a shift in phase angle between forcing func-

PLATE V

THEORETICAL ENGINE MOTION IN FLEXIBLE MOUNT
(APPLICABLE TO ALL TYPE ENGINES)

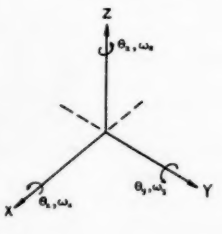
		INSTANTANEOUS VIBRATION AMPLITUDES
TRANSLATION	X AXIS	$x = \sum_n \left[\frac{-1}{4\pi^2 n^2 M_x}\right][a_{nx}\sin n\theta + b_{nx}\cos n\theta]$
	Y AXIS	$y = \sum_n \left[\frac{-1}{4\pi^2 n^2 M_y}\right][a_{ny}\sin n\theta + b_{ny}\cos n\theta]$
	Z AXIS	$z = \sum_n \left[\frac{-1}{4\pi^2 n^2 M_z}\right][a_{nz}\sin n\theta + b_{nz}\cos n\theta]$
TORSION	X AXIS	$\theta_x = \sum_n \left[\frac{-1}{4\pi^2 n^2 I_x}\right][\gamma_{nx}\sin n\theta + \eta_{nx}\cos n\theta]$
	Y AXIS	$\theta_y = \sum_n \frac{I_p}{[I_p\sigma^2 - n^2 I_y][I_x 4\pi^2]}\left[\left\{\gamma_{ny} + a_{nz}\chi_x - \frac{I_p\sigma}{nI_x}(\eta_{nx} - b_{ny}\chi_x)\right\}\sin n\theta + \left\{\eta_{ny} + b_{nz}\chi_x + \frac{I_p\sigma}{nI_x}(\gamma_{nx} - a_{ny}\chi_x)\right\}\cos n\theta\right]$
	Z AXIS	$\theta_z = \sum_n \frac{I_p}{[I_p\sigma^2 - n^2 I_z][I_x 4\pi^2]}\left[\left\{\gamma_{nz} - a_{ny}\chi_x + \frac{I_p\sigma}{nI_y}(\eta_{ny} + b_{ny}\chi_x)\right\}\sin n\theta + \left\{\eta_{nz} - b_{ny}\chi_x - \frac{I_p\sigma}{nI_y}(\gamma_{ny} + a_{ny}\chi_x)\right\}\cos n\theta\right]$

		FORCING FUNCTION EXPRESSIONS
TRANSLATORY FORCES		$F_x = \sum_n [a_{nx} f^2 \sin n\theta + b_{nx} f^2 \cos n\theta]$
		$F_y = \sum_n [a_{ny} f^2 \sin n\theta + b_{ny} f^2 \cos n\theta]$
		$F_z = \sum_n [a_{nz} f^2 \sin n\theta + b_{nz} f^2 \cos n\theta]$
COUPLES		$T_x = \sum_n [\gamma_{nx} f^2 \sin n\theta + \eta_{nx} f^2 \cos n\theta]$
		$T_y = \sum_n [\gamma_{ny} f^2 \sin n\theta + \eta_{ny} f^2 \cos n\theta]$
		$T_z = \sum_n [\gamma_{nz} f^2 \sin n\theta + \eta_{nz} f^2 \cos n\theta]$

DEFINITION OF SYMBOLS:

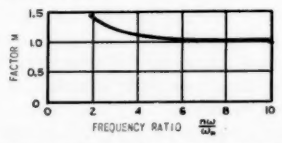
- f = REVOLUTIONS PER SECOND OF ENGINE
- θ = CRANK ANGLE MEASURED FROM MASTER CYLINDER
- I_x = MOMENT OF INERTIA OF ENGINE AND PART OF MOUNTING STRUCTURE DIRECTLY ATTACHED THERETO, ABOUT X AXIS
- I_y = MOMENT OF INERTIA OF PROPELLER, ENGINE, AND DIRECTLY CONNECTED MOUNTING STRUCTURE ABOUT AXIS PARALLEL TO Y AXIS, PASSING THROUGH CENTER OF GRAVITY OF THE COMBINATION
- I_z = SAME AS I_y BUT ABOUT AXIS PARALLEL TO Z AXIS, PASSING THROUGH CENTER OF GRAVITY TO THE COMBINATION
- I_p = POLAR MOMENT OF INERTIA OF PROPELLER AND HUB (PLUS CRANKSHAFT IF DESIRED)
- σ = GEAR REDUCTION RATIO = PROPELLER SPEED / CRANKSHAFT SPEED
- χ_x = DISTANCE OF COMBINATION CENTER OF GRAVITY FROM PLANE OF CYLINDERS (SINGLE ROW ENGINE ONLY)
- M_x, M_y, M_z = SUSPENDED MASS ALONG X, Y, Z AXES.

COORDINATE SYSTEM



NOTE: FOR A DOUBLE ROW RADIAL ENGINE, ALL COEFFICIENTS a AND b ARE ZERO. FACTOR χ_x IS THEREFORE UNNECESSARY. IN A SINGLE ROW RADIAL ENGINE $I_y = I_z$ NORMALLY.

FOR FORCING FUNCTION COMPONENTS OF FREQUENCY LESS THAN TEN TIMES THE NATURAL FREQUENCY OF THE SUSPENDED SYSTEM IN THE SAME DEGREE OF FREEDOM, MULTIPLY THE AMPLITUDE OF MOTION OF THAT FREQUENCY COMPONENT BY THE FACTOR M' OBTAINED FROM THE PLOT BELOW.



CAUTION: FOR VALUES OF THE NATURAL FREQUENCY ω_n ABOUT THE Y AND Z AXIS, USE VALUES CORRECTED FOR GYROSCOPIC AFFECT AS NOTED IN TEXT

tion and forced motion as $n\omega \rightarrow \omega_n$,[10] but this may be neglected unless accurate phase determination is important.

From the relations of Plate V three conclusions may be drawn regarding translational vibration of a freely mounted engine under propeller load:

(1) For vibration frequencies above the mount resonant frequency in a particular degree of freedom, the translational motion is 180° out of phase with the forcing function. (This is indicated by the negative sign.)

(2) The amplitude of engine vibration is, *within limits of the stated assumptions*, independent of engine speed, except for frequencies near the natural mount frequency.

(3) For a given magnitude of forcing function at a given speed, the vibration amplitude is inversely proportional to the square of the harmonic order n.

Angular Vibration about Engine Axes

Engine vibration about the thrust axis is governed by an equation of equilibrium of the form of Eq. (1), but expressed in terms of couples and angular coordinates. The resultant angular motion about this axis is, therefore, analogous to any of the translational motions (Plate V). Angular motions about the Y and Z engine axes are not independent, but are coupled due to the gyroscopic effects of the rotating propeller. In addition, the Y and Z forcing couples in a single row engine are not purely the couples acting due to the work of Part I, but must be augmented by the couples occurring due to the point of application of inertia forces being in the cylinder plane rather than at the center of gravity of engine, propeller and mount. Any torque applied about the Y and Z engine axes is resisted by four couples: (1) An angular acceleration inertia reaction couple of the engine-propeller-mount assembly. (2) The gyroscopic precession couple of the rotating propeller. (3) A couple from the engine mounting springs proportional to angular displacement. (4) A damping couple from the mount friction units.

Precession of the propeller axis due to a Z axis couple will take place about the Y axis. As soon as such precession occurs, however, a new couple about Y acts on the propeller due to acceleration of the engine-propeller-mount assembly about the Y axis, as engine and propeller must move as a unit (excluding deflections); this in turn causes precession about the Z axis. The motions are thus closely coupled and must be solved for by simultaneous equations of the form:

$$I_y d\omega_y/dt + \omega_z I_p \Omega + k_{\theta_y}\theta_y = T_y \qquad (3)$$

$$I_z d\omega_z/dt - \omega_y I_p \Omega + k_{\theta_z}\theta_z = T_z \qquad (4)$$

The symbols used are defined in Plate V. If it is assumed that the forcing frequencies are high relative to the natural mount frequencies, terms in k_{θ_y} and k_{θ_z} may be neglected; under the same assumption the friction effects may also be neglected. The solutions for the engine motion θ_y and θ_z can then be shown to be of the form of Plate V. A further effect of propeller rotation is to introduce an additional restraint which changes the effective natural mount frequencies about the Y and Z axes. Assuming equal restraints about both axes, two natural frequencies can be shown to exist about each axis:*

$$\omega_{\theta_y} = \omega_{\theta_z} = -\frac{I_p\omega\sigma}{2I_y} \pm \sqrt{\left(\frac{I_p\omega\sigma}{2I_y}\right)^2 + \omega_0^2}$$

where ω_0 is the mount natural circular frequency about the Y or Z axes due to the mount springs alone (propeller not rotating). When $I_p\omega\sigma/2I_y >> \omega_0$ the natural mount frequencies become

$$\omega_{\theta_y} = \omega_{\theta_z} = 0,\ I_p\omega\sigma/I_y$$

normally $I_p < I_y$, so the natural mount frequencies are always sub-harmonics of the propeller speed $\omega\sigma$.

Engine Test Technique

On the basis of the work discussed to this point, it is possible to predict the vibration of any radial engine when installed in a flexible mount similar to that of Figs. 5 and 6. To verify the theoretical work, full scale vibration tests have been made on several engines in this mount.

A typical test house installation is shown in Fig. 6 and the diagram of Fig. 7. In order to maintain low spring restraint, the static thrust, dead engine weight, and mean engine torque were taken up by adjustable "bungee" springs. All engine controls were of the Bowdin type and fuel and oil lines passing from rigid to flexible portions of the structure were installed so as to introduce small restraint. Eddies and vortices at the sharp corners of the test house were so severe that use of a flight propeller was impossible, the large propeller diameter causing the blade to pass through the turbulent strata and excite large transient oscillations. Use

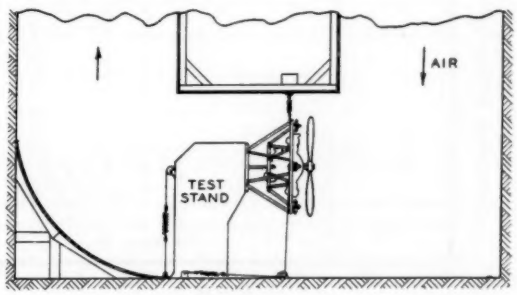


Fig. 7. Test house cross-section showing vibration isolating mount installation and proximity to source of disturbances in air flow.

* For a more detailed study of this phenomenon see reference 9, page 48.

of a small diameter test club decreased transient excitation to a reasonable level.

Gyroscopic and mass effects of the propeller could not be eliminated, but the forcing functions from the propeller were reduced as much as possible. Three blade propellers were used so as to have a constant moment of inertia about any diameter, and propeller balance was checked prior to each test run.

Vibration measurement was accomplished by the M.I.T.-Sperry measuring equipment. Both the instrumentation and measurement procedures have been covered in earlier papers.[1] In order to check the phase of the vibration with respect to the engine crankshaft position, the master cylinder spark impulse was recorded directly on the vibration record trace by methods discussed in reference 11. Vibration records were made for all engine motions at various engine speeds throughout the engine operating range.

Record Analysis

Vibration records for the six motions of each engine were harmonically analyzed on a Coradi Harmonic

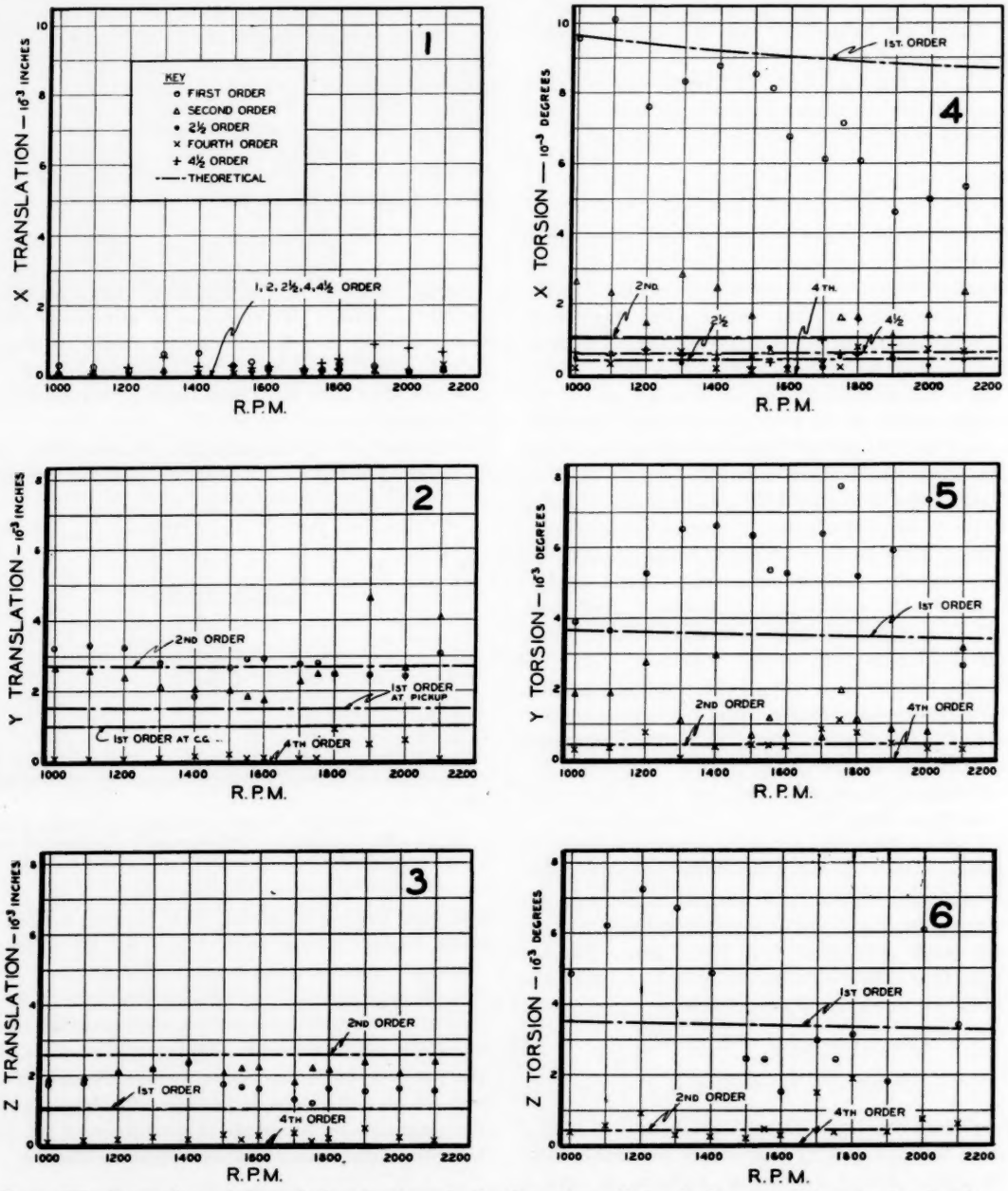


PLATE VI. Comparison of theoretical and measured vibration—nine cylinder single row radial engine in vibration isolating mount. (Dash-dot line represents theoretical amplitude.)

Analyzer. Orders of $^1/_2$, 1, $1^1/_2$, 2, $2^1/_2$, 3, $3^1/_2$, 4, $4^1/_2$, 9, $13^1/_2$, and 18 were separated from nine cylinder engine records, and orders of $^1/_2$, 1, $1^1/_2$, 2, $2^1/_2$, 3, $3^1/_2$, 4, $4^1/_2$, 7, 14, and 21 were separated in the case of the fourteen cylinder twin row engines.

Overall accuracies, including measurement and analysis, can be set at about ± 10 to ± 25 percent for half order vibration (based on engine speed as the fundamental frequency), $\pm$ 15 percent for low speed first order motions, and ± 10 percent for all other orders. Errors due to local structural deflections were minimized by checking the natural frequency of each pickup mounting arrangement. In all cases, this frequency was high compared to any measured engine frequency.

Test Results—Nine Cylinder Engine

Measured vibration amplitudes (one-half total motion) for a nine cylinder test engine are plotted in Plate VI. Theoretical vibration in each case is shown by curves corrected for mount characteristics. Measured translational vibrations are small and agree very well with the theoretical values. In Plate VI-2, the theoretical first order vibration has been corrected to compensate for the displacement of the pickups from the plane of the center of gravity, it being impractical to locate the units in the desired plane.

Curves of angular vibration also agree with the theory in general; X axis motion in particular shows close correlation. The greatest discrepancies between theory and test are in the angular motions about the Y and Z axes. There are three reasons for this:

(1) Part of the forcing couples about these axes are directly proportional to the distance between the cylinder plane and the combination center of gravity (particularly for second order motions). This distance is less than one inch and even reasonable accuracy in

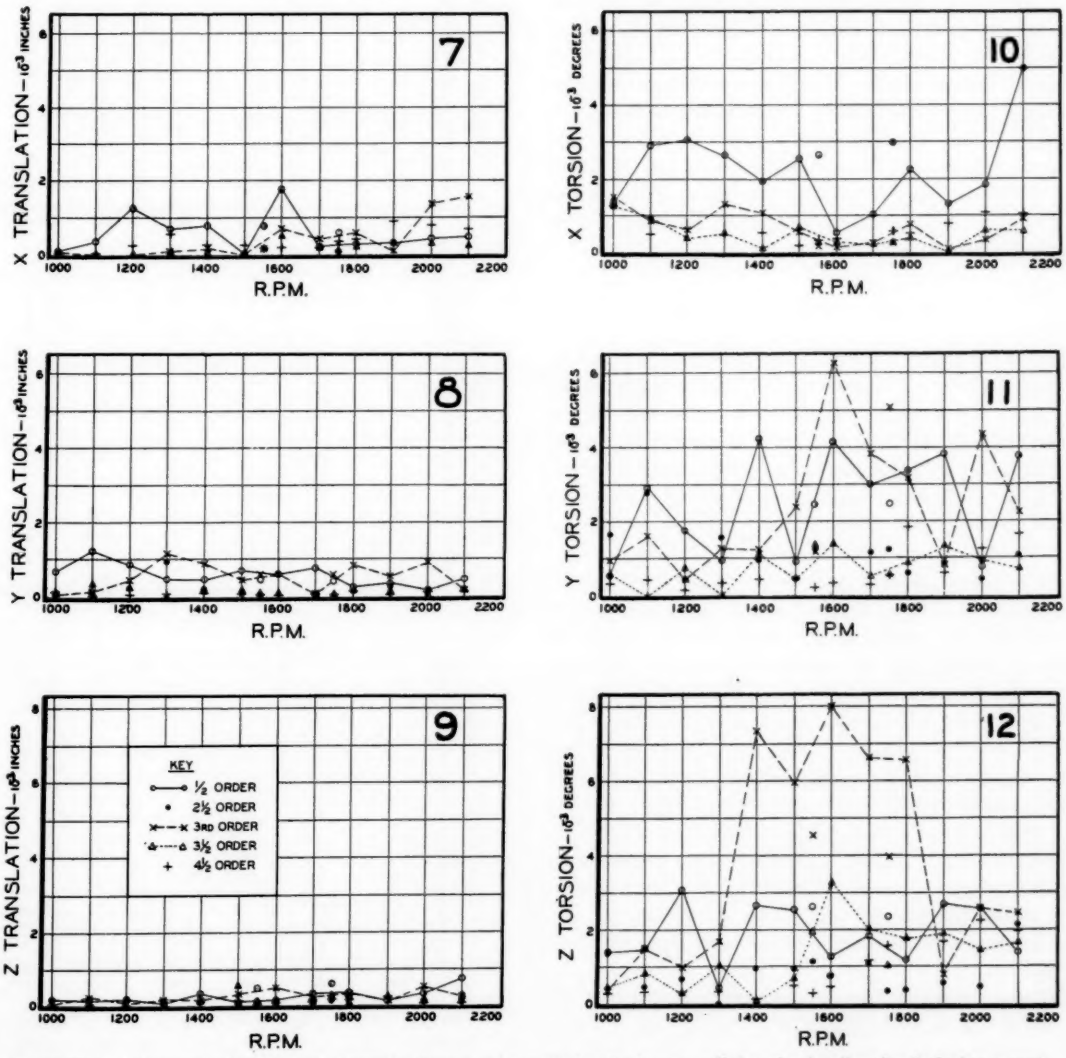


Plate VII. Measured vibration not shown in theory—nine cylinder single row radial engine in vibration isolating mount.

center of gravity prediction may cause large errors in the calculated motions.

(2) The exhaust gas forcing function calculations (first order vibration) are only approximate.

(3) There is a possibility of a first order couple of unpredictable magnitude due to unequal thrusts on the propeller blades. In a geared engine, this effect may be singled out, but in a direct drive engine separation is impossible.

Second order values about the Z axis have been omitted; circuit difficulties in the vibration pick-up prevented accurate analysis of this motion due to 60 cycle a.c. pick-up. The true second order vibration is probably as close to the theoretical as is the Y axis motion.

Several phase angles predicted by theory were checked with test values to within about $\pm$ 20°.

The magnitudes of measured vibration frequencies not shown in the theory are plotted in Plate VII. The largest effects are at $^1/_2$ and 3 times engine speed. Half order motions are due to defective carburetion, distribution, or any effect causing irregularities in the engine cycle, and have been noted as a function that cannot be predicted theoretically. Third order vibration arises from propeller blades passing through the turbulent air strata in the test house; this is verified by the fact that the largest third order motions are about the Y and Z axes, the disturbing air probably being near the top of the test chamber and hence primarily exciting yawing and pitching moments.

Test Results—Twin Row Engine

Plate VIII shows the measured and theoretical vibrations of a twin row radial engine. Translational motion plots are properly omitted from this plate as the theoretical translations are zero; substantially, all measured translational harmonic components were less than 0.001 inch, with 80 per cent of them below 0.0005 in. amplitude (Plate IX).

In the angular vibration about the X axis first and fourth order measured motions are close to the theoretical values. The excess of third order is probably excited by aerodynamic reactions on the propeller blades or possibly by air reactions on the engine itself. About the Y and Z axes, the large first order vibration may be ascribed to improper counterbalancing, or to differential blade loads on the propeller, the latter being the more plausible explanation. The large $2^1/_2$ order recorded motion has appeared in all 14 cylinder twin row engines tested. The alternating couples involved are very large and it is evident that there is some unbalance inherent in this type of engine that has not been accounted for by the theory. This is the only real discrepancy between theory and the empirical values.

Angular vibration frequencies, not predicted by the theory, are included in Plate IX. Translational vibration amplitudes were discussed above. The $2^1/_2$ order motion about the X axis is too large to be explained on the basis of the present theory; the alternating couple required to maintain this motion of 0.0033° at 1600 r.p.m. is about 1000 inch pounds.

Motions about the Y and Z axes are mainly due to half order effects and aerodynamic reactions on the propeller.

Vibration of Single Row Engine in Flight

The engine used in the tests plotted in Plates VI and VII was flight-tested in a standard two-place military airplane. Effects of the high restraints of the airplane engine mount are shown by the vibration characteristics of Plate X. The vibrating system composed of

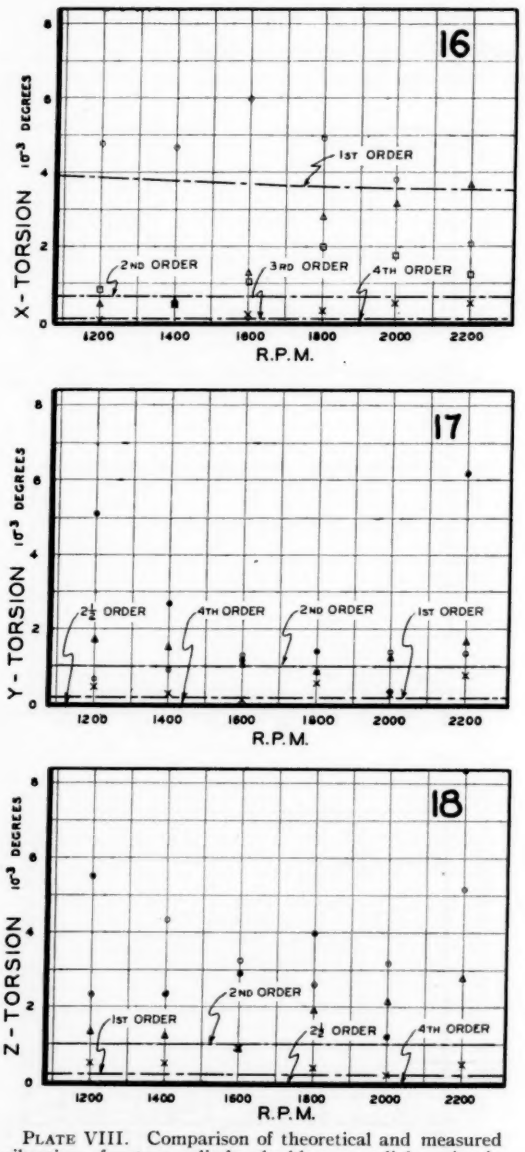


Plate VIII. Comparison of theoretical and measured vibration—fourteen cylinder double row radial engine in vibration isolating mount.

airplane, engine, and mount structure resonated with the first order X axis forcing couple at about 1500 r.p.m. (Plate X-4). This represents an approximate seven-fold magnification of free engine motion.

Accurate evaluation of the resonant engine speed can be made by observing the phase angle shift. In any vibrating system passing through resonance, the phase angle shift between forcing function and forced motion is 180°. Measured phase angles for the X axis angular motion show this characteristic (Fig. 8). The point of 90° phase shift determines the resonant speed as 1550 r.p.m.; the slope of the curve indicates the damping in the system to be about one-twentieth of that required for critical damping. At engine speeds near 1100 r.p.m., the measured vibration about the X axis is lower than that of a flexible engine mount. This is due to the "dynamic vibration absorber" effect of the airplane and indicates an *effective* airplane moment of inertia approximately equal to that of the engine.

Second order vibration amplitudes are close to the corrected measured values for a free suspension. (Values given in Plates VI and VII must be corrected for the additional inertia of the isolated portion of the flexible test mount structure for direct comparison with flight results). First order vibrations about the Y and Z engine axes are of the same order of magnitude as the

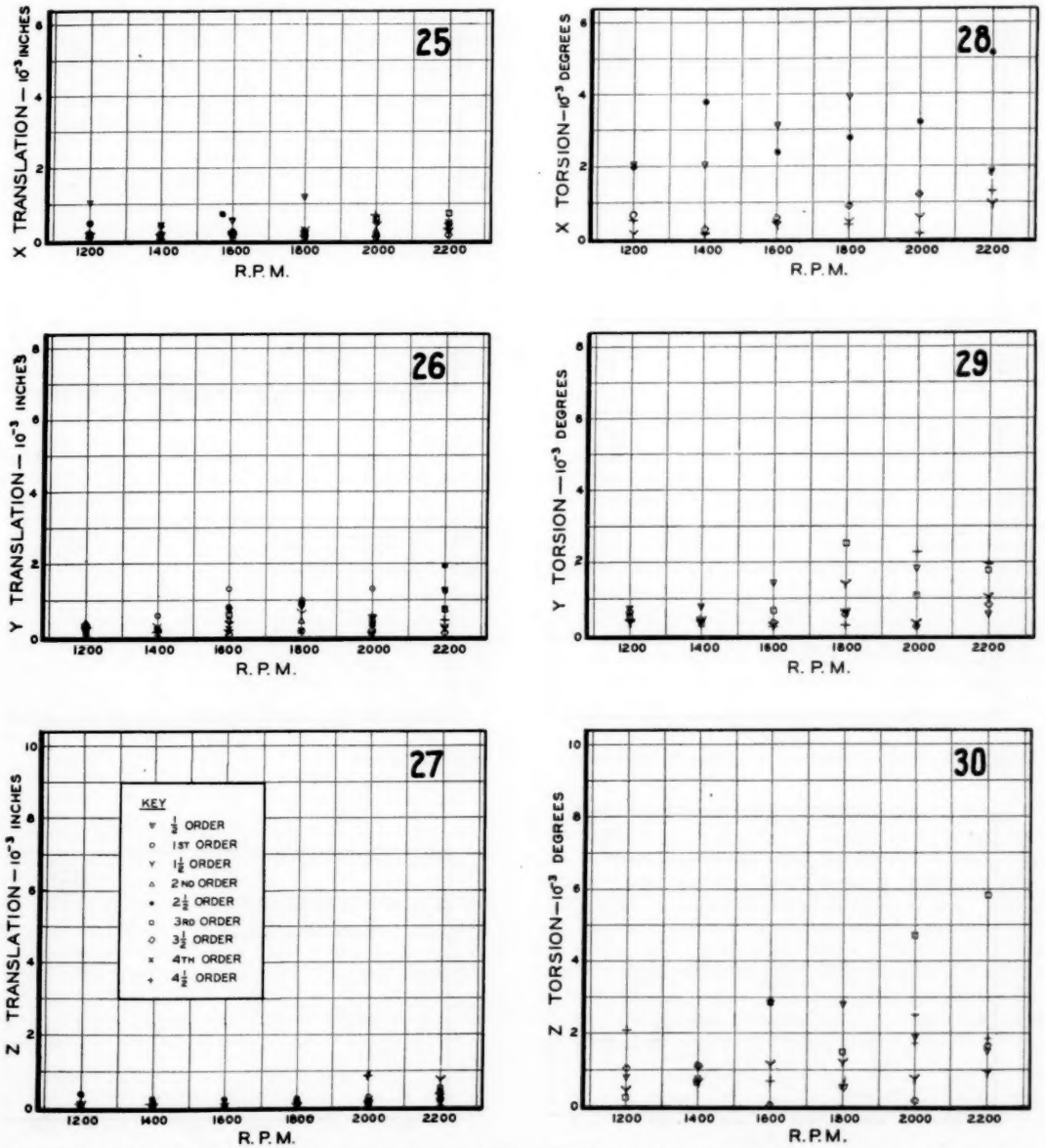


PLATE IX. Measured vibration not shown in theory—fourteen cylinder double row radial engine in vibration isolating mount.

free engine motions. The general upward trend of first order motions at the higher engine speeds, and a similar trend of second order motions at the lower speeds indicates a slight resonance in the gyroscopically coupled systems at about 2400 cycles per minute. Due to exhaust manifolding, the forcing functions due to exhaust gas reactions are negligible. Summarizing, then, the airplane engine mount is amplifying free engine motions about all three axes.

Translational motions are all small. Resonance effects of first order motion along the Y axis are probably the result of displacement of the axis of X rotation from the engine center of gravity due to mount assymmetry. Thus, X rotations have a Y axis linear component at the Y axis pick-ups.

Engine accessory loads are seriously affected by engine mount resonances. In the present example, X axis resonance can increase acceleration loads to seven times the load to be expected on a free engine installation. This is a serious argument in favor of isolated mounting, particularly for accessories with large cantilever overhangs.

Conclusions

The presentation of the theory and test work included in this paper is not a complete summary of the

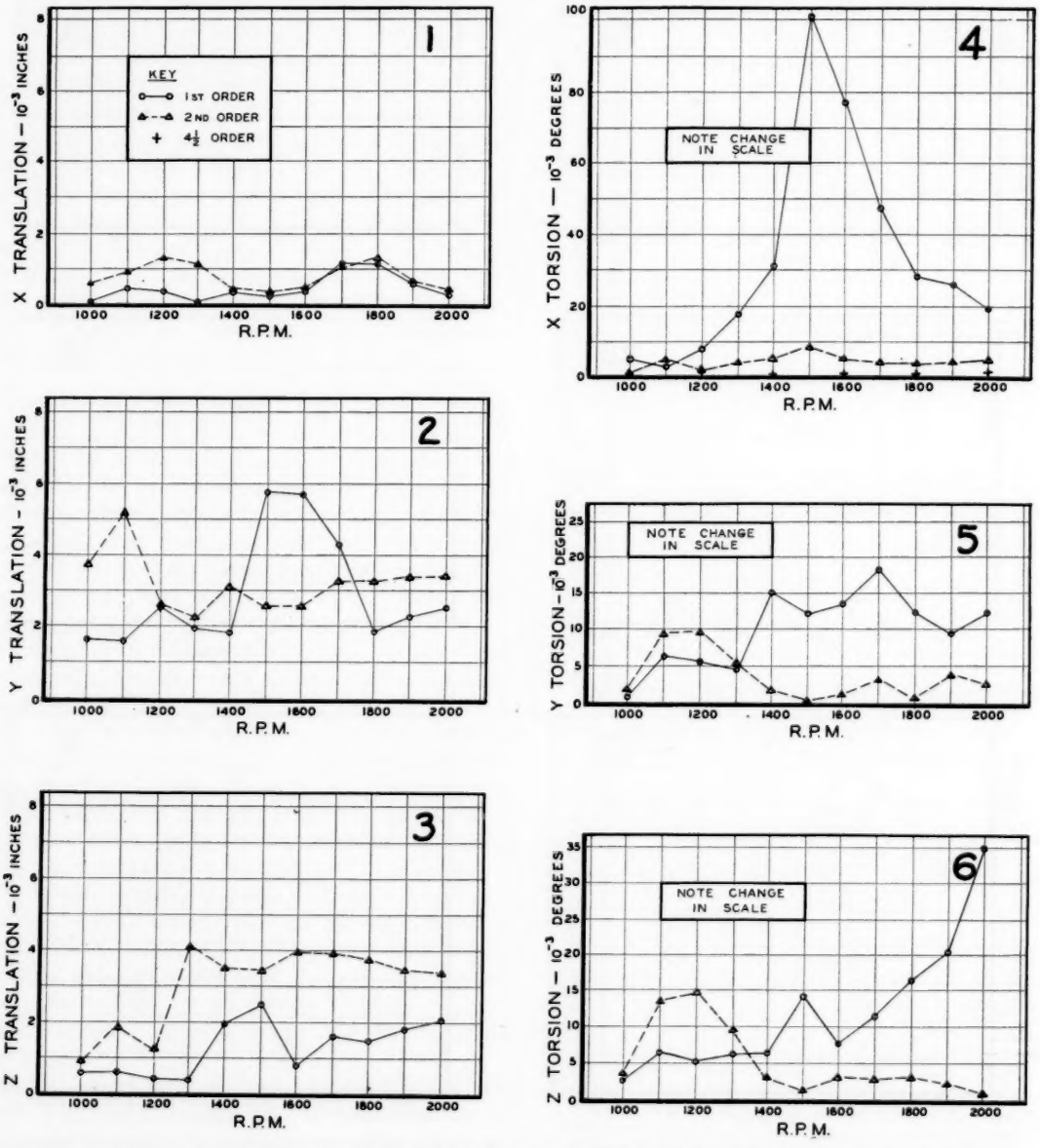


PLATE X. Measured vibration in flight—nine cylinder single row radial engine of Plates VI and VII in military airplane.

work accomplished. However, on the basis of the work presented the following general conclusions are drawn.

(1) Theoretical derivations of engine forcing functions as presented in Plates I and III are substantiated by full-scale tests, and are, therefore, applicable to future engine designs.

(2) Theoretical crankshaft forcing functions (Plates II and IV) are, therefore, substantiated and applicable to crankshaft design of 7, 9, 14, and 18 cylinder engines.

(3) A large $2^1/_2$ order couple exists about the Y and Z axes of twin row radial engines which is not shown by the present theory.

(4) Vibration isolation of large aircraft power plants is essential both in reducing forces transmitted to the structure, and in reducing the stresses in accessory attachments.

(5) Aerodynamic effects on the propeller are an important source of forcing function, particularly on geared engines where the frequency is so low as to possibly excite mount resonance.

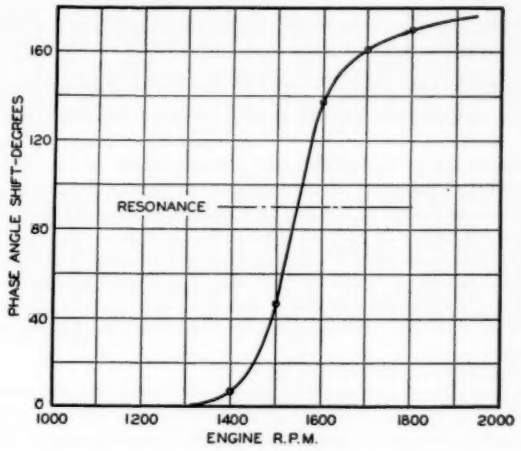


FIG. 8. Phase angle shift at resonance in airplane engine mount.

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[9] Taylor, E. S., and Browne, K. A., *Vibration Isolation of Aircraft Power Plants*, Journal of the Aeronautical Sciences, Vol. 6, No. 2, pages 43–49, December, 1938.

[10] Den Hartog, J. P., *Mechanical Vibrations*, McGraw-Hill.

[11] Bentley, G. P., *Aircraft Vibration Flight Testing*, Journal of the Aeronautical Sciences, Vol. 4, No. 8, pages 316–319, June, 1937.

Book Reviews

The Internal Combustion Engine, Vol. I, Principles, by D. R. PYE; Oxford University Press, New York (second edition), 1937; 289 pages, $5.00.

The second edition of this book is a welcome addition to the aircraft engine literature. It still suffers from the lack of contemporary American data noted by reviewers of the first edition but less so than previously. The excellent chapter on detonation that has been enlarged upon considerably is one of the best available to the student of engine design. It is somewhat to be regretted that Mr. Ricardo's work still forms such a substantial foundation for the whole volume, but Mr. Pye's outstanding ability and activity as Scientific Director of Research for the British Air Ministry has made the book a most useful one.

VAL CRONSTEDT
Pratt & Whitney Aircraft

The Aircraft Flight Instructor, by CAPTAIN R. DUNCAN, M.C.; The Goodheart Willcox Company, Inc., Chicago, 1938; 309 pages.

With the great expansion of flight training a number of books are available as ground school texts. The present volume is a very readable and informative account of the many phases of elementary pilot training. The author, a former Flight-Commander with the R.A.F. and a licensed pilot in both the United States and Canada, is well qualified for the preparation of a book of this kind.

After a short introductory chapter on the qualifications and equipment of a pilot, the parts of an airplane and its control system are described. The following chapter on "How Flight is Accomplished" gives a short but good account of the aerodynamic forces on an airplane and its propeller. Discussions and explanations of stability, dynamic loads in maneuvers, performance, the execution of maneuvers, performance, parachute jumping, acrobatics, spinning, seaplanes and amphibians, the aircraft compass, instrument flying, meteorology, navigation, icing, instruments, and instrument and engine trouble shooting, comprise the remainder of the book. The illustrations are numerous and excellently done.

Aeronautical Training, by CHARLES ZWENG; Annapolis, 1939; 92 pages (lithographed).

This is a book of questions and brief answers designed to help the student who is preparing to pass his written pilot's examination. It is divided into six parts, dealing with Aircraft, Engines, Avigation, Meteorology, Air Commerce Rules including Air Traffic Rules, and General Examination Questions. Eight illustrations give schematic diagrams of a wing panel, ignition system, fuel system, and various engine parts. While the book cannot be recommended as a text, since the answers are in many cases too brief to give an adequate explanation of the phenomena considered, it may be advantageously used to supplement an intensive study of the various subjects in standard works.

Institute Notes

Preliminary Announcement for the International Congress of the Aeronautical Sciences

Following is the preliminary announcement of the International Congress of the Aeronautical Sciences. The Congress is being sponsored by the Institute and will be held in New York from September 11 through September 17, 1939.

Fifty foreign countries have been invited to send official delegates to attend as a tribute to the aeronautical scientific contributions of the Wright Brothers. Delegates from foreign universities, laboratories, and aeronautical organizations are also expected.

Following is the tentative program:

Monday, September 11

Afternoon—Registration and Opening Session at Columbia University.

Evening— Reception and Ball in honor of the Delegates at The Waldorf-Astoria Hotel.

Technical Sessions at Columbia University

Tuesday, September 12

Morning— (Simultaneous Sessions):
Aerodynamics
Engines

Afternoon—Air Transport

Wednesday, September 13

Morning— (Simultaneous Sessions):
Aircraft Design
Meteorology

Afternoon—Radio and Instruments

Thursday, September 14

Morning— (Simultaneous Sessions):
Aerodynamics
Physiological Problems

Afternoon—Structures

Friday, September 15

Morning— Propellers

Afternoon—Fuels and Lubricants

Evening— Banquet to Delegates
The Waldorf-Astoria Hotel
Each nation and organization will present letters of tribute to the Wright Brothers. These will be bound and sent later to Mr. Orville Wright.

Saturday, September 16

"International Aviation Day"
New York World's Fair 1939
at the Fair Grounds

Sunday, September 17

Luncheon and all day Lawn Party for Delegates
The Aviation Country Club
Hicksville, Long Island, New York

Columbia University has offered to provide rooms without charge in the Residence Halls for one hundred Delegates during the week of the Congress. Preference will be given to foreign Delegates in the assignment of rooms.

Acceptances have been received from a considerable number of foreign Delegates, many of whom will present papers. It is suggested to members of the Institute and all others interested in Aeronautics who are planning to visit the New York World's Fair 1939 that they consider the advantages of attending during the week of the Congress.

Complete announcements giving the entire program will be sent to members as soon as practicable, and will be printed in the Journal.

For the convenience of those who are attending the meeting of the Union Géodésique et Géophysique Internationale in Washington, D.C., during the same week, the Meteorology session listed above as occurring on Wednesday, may be shifted to Friday afternoon.

Joint Meeting of the Institute and the Soaring Society of America

From Friday June 30th through Sunday July 2, 1939, the Institute and the Soaring Society of America are holding a joint meeting at Elmira, New York, in connection with the Tenth Annual National Soaring Contest, being held from June 24th to July 9th. Following is the tentative program for the meeting:

Friday, June 30

Morning and early afternoon—
Visit to Warren E. Eaton Motorless Flight Headquarters. Tour of facilities, inspection of sailplanes, observation of launching operations.

4:00 p.m.—Special demonstration of launching methods and flying and landing techniques.

6:00 p.m.—Picnic supper for participants in the Contest and the Joint Meeting, and other guests.

7:30 p.m.—Opening Session of Joint Meeting, Administration Building, Harris Hill:
R. E. Franklin, Chairman, S.S.A. Meeting Committee, "*Address of Welcome.*"
Arthur L. Lawrence, Chairman, Contest Board, S.S.A., "*Ten Years of Soaring in the United States.*"
R. C. du Pont, President of S.S.A., "*American Soaring Technique Today.*"
Presentation of Warren E. Eaton Memorial Soaring Trophy by Committee of Awards.

8:30 p.m.—Technical Forum on Sailplane Design.

Saturday, July 1

8:00 a.m.—Pilots' Meeting, Harris Hill.

10:00 a.m.—Session on Aeronautical Meteorology, Elmira College.
CHAIRMAN, F. W. Reichelderfer, U.S. Weather Bureau.
Peter Riedel, Assistant to the Military and Air Attaché, German Embassy, "*Meteorological Conditions for Soaring.*"
E. J. Minser, T.W.A., "*Meteorological Conditions with Aircraft Strikes and Range Study.*"
K. O. Lange, Blue Hill Observatory, "*Air Current Measurements in the Atmosphere.*"
F. W. Reichelderfer, U.S. Weather Bureau, "*Prospective Developments in Weather Service for Aeronautics.*"

12:15 p.m.—Elmira Area Soaring Corporation Luncheon at the Mark Twain Hotel.

2:00 p.m.—Session on Glider Design and Operation, Elmira College.
W. Klemperer, Douglas Aircraft Company, "*Research Problems in Towed Flight.*"
R. C. Platt, E. A. Stalker, M. Stoughton, and E. Jacobs (titles to be announced).

7:30 p.m.—Elmira College.

W. Georgii, Flugmeteorologisches Institut der Technische Hochschule, Darmstadt, Germany, "*Soaring in the Substratosphere.*"

Informal supper at Hill Top.

Sunday, July 2

All Day "Open House" by pilots of Tenth Annual National Soaring Contest, Harris Hill.

"Aviation on Parade" at the University of Michigan

"Aviation on Parade," a unique air show, was held at the Ann Arbor airport on May 20th and 21st. The show was arranged by the University of Michigan Student Branch of the Institute, in collaboration with other local aeronautical and civic organizations.

About 2500 people took advantage of the opportunity to inspect more than two dozen planes of the private flying class and to witness flight demonstrations designed to take "the mystery out of aviation" and to demonstrate "the ease and safety of private flying." While an announcer described the features of each plane over a public address system, it was sent through a routine demonstration. There were also demonstrations of precision flying and landing.

Besides 11 locally owned planes which were on display, 12 planes were flown to Ann Arbor by various manufacturers especially for the show. These included three Continental Motors planes: the Luscombe, made in Trenton, New Jersey; the Cub, Lockhaven, Pennsylvania; and the Waco, Troy, Ohio. Others on display were: Taylorcraft, Alliance, Ohio; air-cooled Cub, Syracuse, New York; Aeronca, Cincinnati, Ohio; Stinson Reliant and Stinson 105, Wayne, Michigan; Porterfield, Kansas City, Missouri; Dart, Columbus, Ohio; Fairchild, Hagerstown, Maryland; and Rearwin, Kansas City, Missouri.

The Student Branch of the Institute held a banquet in the Michigan Union on May 20th, in conjunction with the air show. Robert H. Hinckley, Chairman of the C.A.A. was the guest of honor and spoke on the C.A.A.'s proposal for the training of private pilots and its significance. He stressed the fact that the program is primarily a peace-time venture for the purpose of furthering interest in private flying. Other speakers were: William B. Stout, Detroit aviation pioneer; Col. Floyd Evans, State Aeronautics Director; Cyril C. Thompson, Assistant to the President of United Air Lines; and Dean Henry C. Anderson of the College of Engineering. About 125 people attended the banquet.

The following officers of the Student Branch for the coming school year were announced: Leon Z. Seltzer, Chairman; Robert E. Britton, Secretary; James S. Wilkie, Treasurer; Daniel Grudin, Engineering Council Representative; and Prof. M. J. Thompson, Honorary Chairman.

Gift from University of Minnesota Student Branch

The Institute gratefully acknowledges the gift of a photographic copying stand from the University of Minnesota Student Branch. This consists of a glass-top table on which copy can be placed and a vertical camera mounting with micrometer adjustment. The use of this device will greatly facilitate the preparation of slides for the "Simultaneous Lectures" programs.

Branches

Boeing School of Aeronautics. A meeting of this Student Branch was held on April 27th. The "Simultaneous Lectures" program consisting of the papers, "Current Progress in Flight Testing" by N. F. Scudder of the Glen L. Martin Company, and "Some Structural Problems Pertaining to Pressurized Fuselages" by L. F. Engelhardt of the Curtiss-Wright Corporation, was given. Robert T. Lamson and Boyd E. Quate, respectively, presented the lectures.

Polytechnic Institute of Brooklyn. At a meeting of this Student Branch on April 27th, the following officers were elected for the next school year: Robert Kidder, Chairman; William Miles, Vice-Chairman; and Sebastian Nardo, Secretary-Treasurer. Dr. R. P. Harrington, Honorary Chairman. At a meeting on May 11th, Dr. Harrington spoke on the N.A.C.A. laboratories at Langley Field.

Carnegie Institute of Technology. About twenty members of this Student Branch attended a meeting on April 13th, at which B. F. Grimm, Jr., discussed the papers at the Annual Meeting of the Institute. The discussion was based on Prof. Klemin's résumé, which comprised the March "Simultaneous Lectures" program.

Casey Jones School of Aeronautics. At a meeting of this Student Branch, on April 20th, the Engelhardt paper was presented by Nicholas Kintzer, assisted by Ralph Vander Muellen and Albert Perry. Following this the Scudder paper was presented by Gerald Backer, assisted by Walter Krzymowski. About thirty members and guests attended the meeting.

Catholic University. On April 4th, the résumé of the Annual Meeting papers was presented to the members of this Student Branch.

University of Cincinnati. A meeting of this Student Branch was held on May 13th, at which Prof. Bradley Jones spoke on the N.A.C.A. laboratories at Langley Field, following which the Scudder paper was presented.

University of Detroit. A joint meeting of this Student Branch and that of the S.A.E. was held on April 11th. H. O. Setter, instructor at the Detroit City Airport spoke on the use of the Link Trainer for blind flight instruction, and M. J. Kittler, of the Holley Carburetor Company, described the non-icing carburetor recently developed by his company. An interesting discussion followed the papers.

Georgia School of Technology. At meetings on April 21st and May 4th, the "Simultaneous Lectures" program comprising the papers "A Terrain Clearance Indicator" by Lloyd Espenschied and R. C. Newhouse, and "Instruments for Blind Landing" by J. Lyman and F. L. Mosely, respectively, was presented. The latter paper was presented by W. R. Weems. 15 to 20 students and guests attended each meeting.

Stanford University. On April 24th the members of this Student Branch were privileged to inspect the Boeing 314 at Treasure Island, San Francisco. At a meeting on May 1st the Engelhardt and Scudder papers were presented by Profs. Alfred S. Niles and Elliott G. Reid, respectively. Interesting discussions followed the presentations.

Tri-State College. The last meeting of the school year was held on May 15th, at which the Engelhardt and Scudder papers were given. Following are the officers elected for the next school year: Guy Nash, Chairman; Alexander McCullouch, Vice-Chairman; and Sidney Hammarlund, Secretary-Treasurer.

Personnel Opportunities

The Personnel Bureau serves individual members, as well as organizations seeking to employ aeronautical specialists. Any member or organization may have requirements listed without charge.

Wanted

Stress Analysts and Project Engineers for permanent positions. Knowledge governmental and military requirements essential. Seven years' minimum experience required. Eastern location. Reply Box 89, Institute of the Aeronautical Sciences.

Layout men with experience in military and commercial all-metal design. Men with flying boat experience preferred. Eastern location. Reply Box 90, Institute of the Aeronautical Sciences.

Necrology

CHARLES DE FOREST CHANDLER

Col. Charles de Forest Chandler, United States Army, retired, a Founder Member of the Institute, died at his home in Washington, D.C., on May 18, 1939.

Col. Chandler was one of this country's aviation pioneers, becoming interested in aviation while the Wright brothers were experimenting with their first airplane. He made his first balloon flight from Pittsfield, Massachusetts, in 1906. In 1907 he qualified as a free balloon pilot, won the Lahm trophy, and participated in the international balloon race. He was placed in charge of the new Aeronautical Division of the Army where his duties involved the preparation of the specifications under which the first Wright airplane was purchased. In 1909 he served as a member of the War Department board which conducted trials and accepted the first Wright Airplane In 1911 he was appointed commander of the first Army Aviation School, at College Park, Maryland. From 1913 to 1916 he was, successively, Chief Signal Officer in the Philippine Islands, instructor in the Army Signal School, and Signal Officer for General Pershing's expedition into Mexico. In 1916, assigned to undertake the development of balloon service for the army, he organized the Balloon Section of the Aviation Section of the Signal Corps, of which he was in charge in France until his return to this country in 1919. From that time until his retirement on October 16, 1920, he was Chief of the Balloon and Airship Division of the Army. Since 1925 Col. Chandler has been Aeronautical Editor for the Ronald Press.

Born in Cleveland, Ohio, on December 24, 1878, he served in the U.S. Army from 1898 until his retirement in 1920 with the rank of Colonel. He attended the Case School of Applied Science from 1899 to 1901 and was graduated from the Army Signal School at Fort Leavenworth in 1911.

Col. Chandler was the author of many technical articles and the co-author of two books, "Free and Captive Balloons" with R. H. Upson, and "Balloon and Airship Gases" with W. S. Diehl.

He was named an officer of the Legion of Honor of France in 1919 and received the Distinguished Service Medal for his war time activities. In addition to being a Founder Member of the Institute, he was a member of the Society of Automotive Engineers, the National Aeronautic Association, and the Phi Delta Theta fraternity. His clubs were the Army and Navy in Washington, Chevy Chase, Cleveland Athletic, and the Army and Navy in Manila.

Book Reviews

Atmosphärische Turbulenz, by HEINZ LETTAU; Akademische Verlagsgesellschaft, Leipzig, 1939 (in German); 275 pages, R.M. 18.

This book should be invaluable to those interested in the field of atmospheric turbulence, since it brings together a large number of experiments and theories and correlates them, insofar as present concepts permit.

The author first discusses atmospheric flow in general, stressing the role played by turbulence. There follows a short historical account of the development of present concepts from those of the early Greek philosophers and Leonardo da Vinci to present day investigators.

Three succeeding chapters take up the fundamentals of laminar flow in tubes and in boundary layers. Velocity, temperature, and water vapor boundary layers are discussed.

Following this, turbulent flow and the wind near the surface of the earth are treated. The subjects include stability, Reynolds Number, Richardson Number, apparent stresses, vertical transport of properties, mixing length, roughness, effect of turbulence on the resistance of bodies, and wakes behind bodies.

Considerable space is devoted to the Ekman Spiral and modifications due to Rossby. Vertical distributions of velocity, temperature, water vapor, dust, pollen, etc., are developed under various assumptions. Some of the available measurements are given.

Structure of the wind near the earth's surface and at heights is taken up next. Diagrams on which lines of equal velocity and direction as a function of the time or distance give a visual picture of the irregularity of the fluctuations from the mean value. In this connection the work of Sherlock and Stout (Special Committee on Airships, Report No. 2, Stanford University Press, 1937) at Ann Arbor might have added to the completeness of the data presented. Measurements of Austausch, Mischweg, and standard deviation are given.

The next chapter treats flow and shearing stresses in the atmosphere from the standpoint of tensor analysis. This is applied to the general turbulence theory.

There follow short chapters on turbulent fluctuations, and on techniques and instruments for turbulence measurements.

The last chapter treats large scale wind fluctuations; those with periods of days. These are connected with the movement of cyclones and anti-cyclones.

An extremely valuable part of the book is an extensive bibliography of 246 references to the literature.

Brown's Signalling, by W. K. STEWART; Brown, Son and Ferguson, Ltd., Glasgow, 1939; 220 pages, 3s. 6d.

For seaplane pilots who fly over ocean routes this handbook will be invaluable. It describes all methods of signalling and gives all the necessary instruction in the International Code of Signals. The book is issued in seven languages and may be regarded as a standard work in its field. Instruction in visual and telegraphic signalling are presented in such a manner as to provide a progressive course of study for those who desire to acquire proficiency in modern signalling. In case of a forced landing at sea the book would be useful for communication with rescue ships.

The Royal Air Force, by F. V. MONK and H. T. WINTER; Blackie and Son, Ltd., 1938; 223 pages, 3s. 6d.

This book aims to acquaint parents and sons with the advantages of a flying career in the R.A.F. Coming as it does at a time when the British air arm is undergoing such extensive expansion it will no doubt be widely read in England and the British dominions and dependencies.

While its principal purpose may be regarded as an effort to arouse the interest of young men and to get them to "join up," it has a broader value to those in other countries. It gives information regarding life in the R.A.F. and presents descriptions of English military airplanes and engines.

The book is well written and gives some idea of the training necessary to become a pilot or to engage in any of the many aviation pursuits required by modern warfare.

Aeronautical Reviews

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

Effect of a Screen Grid on the Turbulence of an Air Stream. W. L. Towle, T. K. Sherwood, and L. A. Seder. Technique previously developed for measuring diffusion in a turbulent gas stream was employed to study the turbulence conditions downstream from a wire grid in a 30.5-cm. duct. *Industrial and Engineering Chemistry, Ind. Ed.*, April, 1939, pages 462–463, 2 illus., 1 table.

On High-Speed Wind Tunnels. B. V. Korvin-Kroukovsky. Experiments on efflux of gases from orifices show that important changes occur in properties of a gas accelerated to high velocity, apparently due to changes in distribution of molecular energies. These changes indicate that conditions of air flow around a body depend not only on relative velocity but on absolute velocity as well. Results of model tests obtained in wind tunnels at velocity approaching that of sound do not correspond to the practical case of a body moving through still air. Occurrence of compression shock appears to represent the characteristic of the high-speed air stream, rather than the high relative velocity of the model and the air.

Comparison of photographs of shock wave taken in N.A.C.A. high-speed wind tunnel in test of the airfoil, and of a bullet moving through still air indicates entirely different nature of air condition. Former shows that large volume of air is affected by shock waves and that disturbances just begin at maximum cambers of upper and lower surfaces and increase gradually over a short length of travel and then suddenly acquire large properties. Photograph of bullet shows isolated thread-like images indicating well-localized wave formations most pronounced on the nose. *Journal Franklin Institute*, April, 1939, pages 460–471, 3 illus.

Influence of Slipstream of the Propeller. J. Kampé de Fériet and A. Fauquet. Influence of propeller slipstream on the aerodynamic characteristics of a motorized model. Exploration of the aerodynamic field indicates that the deflection increases considerably with speed of rotation. The stream of slipstream air being helicoidal, deflection is greater to the right than to the left, and rudders are affected in a dissymetrical fashion. Presence of the wing increases the coefficient of power of the motor. Abstract of report of the Groupement Français pour le Developpement des Researches Aéronautiques (French N.A.C.A.). *Les Ailes*, April 6, 1939, page 7.

The New Type of Aerofoil Section. C. N. H. Lock and J. H. Preston. Further simplifications, for designers, of the formulas for transformed wing sections. New sections, for ease of computation of shape and flow are said to represent a marked improvement over the Kármán-Trefftz and the N.A.C.A. methods of designing airfoils. The symmetrical shapes of the (P) airfoils have the property of approximate similarity for different thicknesses which is not shared by the generalized Joukowski (Kármán-Trefftz) family. Unsymmetrical shapes of (P) airfoils are also considered. *Aircraft Engineering*, April, 1939, pages 151–152, 3 illus., 1 equation.

The Optimum Size of Models for Studying Flow through Nests of Tubes. R. P. Wallis. Deviation in behavior of the model and prototype and gage sluggishness are considered in relation to a specific research carried out by the author and C. M. White. Problem was to determine how fluid moved through nests of tubes. General nature of the flow over the tubes; factors determining size and proportion of experimental plant; flow through staggered and parallel nests; experimental apparatus to study flow; and method of calculations. Proportions of the individual tubes, their size, and the number of rows and speed at which the nest should be tested are shown to be fixed by considerations which are discussed numerically. *Engineering*, April 28, 1939, pages 487–489, 6 illus., 1 table, equations.

Turbulence and Diffusion. H. L. Dryden. Modern developments in the experimental and theoretical aspects of turbulence in relation to the process of diffusion are reviewed. Concept of isotropic turbulence, its description in terms of intensity and scale, and its experimental realization are discussed at some length. Taylor's theory of diffusion by continuous movements is described and illustrated by his application of the theory to the diffusion of heat from a line source in an airstream with isotropic turbulence. Reynolds' description of non-isotropic turbulence is given in terms of mean values of products of fluctuations of velocity components and of methods now available for measuring these mean values in two-dimensional flow. von Kármán's description of scale characteristics of non-isotropic turbulence in terms of correlation tensors, recent results on mixing of jets with surrounding air, and practical means of securing large turbulence to promote rapid mixing are discussed. *Industrial and Engineering Chemistry, Ind. Ed.*, April, 1939, pages 416–425, 8 illus., 16 equations.

Wind-Tunnel Equipment of Messrs. Blackburn Aircraft, Limited. Closed-circuit type of tunnel has a rectangular working section 7 ft. wide by 5 ft. deep, and an 8-ft. four-bladed fan. Wind-speed range obtainable is from 60 to 180 ft./sec., and corresponding range of Reynolds Numbers at which tests can be carried out is from 0.3×10^6 to 0.9×10^6. Long description including: tunnel construction; 100-hp. variable-speed motor and auxiliary motor driving the fan; special compact form of U-tube for accurate measurement of wind speed; and Cambridge precision manometer employed for calibration, for certain forms of sensitive plotting, and for other purposes, and operating on the same principle as the Chattock gage. To be continued. *Engineering*, April 14, 1939, pages 423–425, 7 illus.

Wind-Tunnel Equipment of Messrs. Blackburn Aircraft, Limited. Farren type of aerodynamic balance, designed jointly by Blackburn Aircraft, Ltd., and Cambridge Instrument Company, is capable of measuring lifts up to 500 lb., drags up to 100 lb., and pitching moments up to 50 lb.-ft. Balance, attachment of model to framework of the balance, subframe for measuring of pitching moment, arrangements for weighing forces, means for raising and lowering stirrups to remove and apply weights, and two Cambridge hot-wire micrometers employed for single-force measurements are described in great detail. *Engineering*, April 21, 1939, pages 461–464, 22 illus., 14 on Plate XIX.

Aircraft Design

The Coming Years. H. E. Wimperis. Speeds will no doubt exceed 500 but probably not 600 m.p.h., height may be pushed though probably not a great deal above the present maximum of 56,000 ft., range will certainly be increased as new materials come forward, but the striking increase in the coming years will be increase in size. Flying boat of 100 tons, possibly 200 tons, could be built and engined at once. Possibilities in new materials and new structures are discussed. Strategic position of Australia in the Pacific as a source of munitioning strength for R.A.F. needs in the Far East is pointed out. *Aeroplane*, April 5, 1939, pages 425–426.

An Elementary Study of the Spin. J. H. Crowe. Stagger of biplanes; tandem wings; backward stagger; data on wing profiles and their rolling properties; high camber airfoils; plan form of wing; elliptical wing; sweepback; and combined taper and sweep. Effect of these factors upon the stall are considered in detail. Continued. *Aircraft Engineering*, April, 1939, pages 158–160.

Three New Balanced Flaps. W. E. Gray. Test results with a modified Irving design, a slotted flap, and a modified Zap type. One of the flaps has been thoroughly tested on a very large model on a car at high speeds and results may be regarded as beyond doubt, while the other two have been tested in a tunnel at low Reynolds Number. Similar tunnel tests on a plain split flap are in close agreement with car tests on like flap, and this gives a reasonably good assurance of validity and accuracy of tunnel results.

First flap is of the type invented by Mr. Irving of the National Physical Laboratories four years ago and modified by cutting off the rear third of the lower half of the flap and reattaching it with a hinge. Second flap is an attempt to improve upon the well-known Handley-Page type of slotted flap. Method is to hinge a forwardly-projecting balancing and fairing surface to the nose of the slotted flap, and to control this balance surface by linking it suitably to the wing. Third flap is an improvement on the once well-known Zap type. Leading edge of flap is allowed to move back along a suitably shaped track instead of limiting its motion to a straight line. Whether the shielding of nose part of the flap as it moved up into the wing would alter the characteristics for better or worse was investigated. *Flight, Aircraft Engineering Sup.*, April 20, 1939, pages 13–15, 8 illus.

Stress Analysis and Structures

The Analysis of Leading-Edge Wing Beams. J. S. Newell. Wing beams having a single shear web, located at about 30 percent wing chord, plus a stress-carrying sheet running around the leading edge are, in case of most airfoils, unsymmetrical sections and should be analyzed as such. Because of thinness of shear carrying elements, special care is required in determining distribution of shear stresses around the cross-section. Procedure is developed whereby normal tensile and compressive stresses, and shear stresses, may be determined in a straight-forward manner. Since internal shear stresses acting upon each unit area in the cross-section result in forces tending to twist the beam, unless there is coincidence of the lines of action of the resultants of internal shear forces and of the external forces producing shear on the cross-section, it is imperative that means be provided for determining "shear center" or "center of twist" of the beam so that magnitudes of such torsional couples may be evaluated. Formulas are developed for accomplishing this, and an example is presented to illustrate their use. *S.A.E Preprint for National Aeronautic Meeting*, March 16–17, 1939, 12 pages, 3 illus., 3 tables, 13 equations.

The Effects of Rivets and Surface Roughness on Wing Drag. M. J. Hood. Effects of common surface irregularities on wing drag, as determined in N.A.C.A. wind-tunnel tests. Increases in wing drag caused by representative arrangements of protruding and countersunk rivet heads, lapped sheet-metal joints, and surface roughness are demonstrated as well as effects of varying rivet size, spanwise rivet pitch, and chord position of the forward row of rivets. Manufacturing irregularities are shown to be responsible for considerable excess drag over and above that due to rivets and lapped joints. Method is suggested for estimating drag due to rivets and lapped joints under conditions of dynamic scale and of rivet and lap size and arrangement outside the range of the tests. Estimated excess drag caused by rivets and lapped joints on the wing of a large airplane, and gain attained by eliminating rivets and laps from various portions of the wing are illustrated in an example. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 8 pages.

The Plastic Airplane. Development and progress being made in the application of synthetic resins to aircraft, with brief descriptions of the application of "improved" wood, the Harte-Still method, the Atwood method making use of mandrels and cores around which the plastic-impregnated wood veneer or other reinforcing medium is wrapped and cured and a method in which large metal molds are used to shape the wood-plastic composition. Quotations from articles previously published. *Modern Plastics*, March, 1939, pages 41, 66, 68, 3 illus.

Torsion of Tapered Tubes. J. Hanson. Effect of the various parameters on torsional stiffness of a tapered rectangular tube of proportions representative of an airplane wing under a concentrated torque applied at a section equivalent to the average "midaileron" section. Analysis of the problem is based on the stress distribution in an axially constrained tapered tube given by Williams in R. & M. 1761 and the stiffness obtained is compared with that for a tube with simple shear stress distribution of the Bredt-Batho type for a tube with free ends. Results of R. & M. 1761 (for the type of loading considered) are given in a rearranged form allowing accurate computation to be more easily made. *Aircraft Engineering*, April, 1939, pages 145–147 and 160, 5 illus., 37 equations.

The Photoelastic Method as an Aid in Stress Analysis and Structural Design. B. F. Ruffner, Jr. Photoelastic method may be utilized quickly to reduce statically indeterminate problems to statically determinate ones. In many cases if structural elements have varying moments of inertias or a large number of redundancies, analytical solutions are difficult and impracticable. Photoelastic method is quick and accurate as the stress analyst has a vivid picture of the stress distribution. Various sizes and placements of stiffeners for the ring could be quickly tested.

Examples given were selected because the problem of monocoque ring analysis is difficult mathematically, particularly if rings are non-uniform in section, or are stiffened with cross members. Photoelastic polariscope and equipment used at Oregon State College are described and analysis of fringe pattern and solution of maximum moment are explained. *Aero Digest*, April, 1939, pages 60–61, 6 illus.

Isopachic Stress Patterns. M. M. Frocht. Isopachic stress pattern and inherent plane of symmetry are defined. Optical method for isopachic is discussed, including: brief theory of interference fringes; deformation of a flat surface in a two-dimensional stress system; interferometer or datum plane; optical path; balancing or adjusting head; loading; the particular problem and model; analysis of results; boundary stresses; stresses across sections of symmetry and across arbitrary radial section; patterns of a solid glass disc subjected to load; extension of method to non-symmetrical bodies; significance of isopachic patterns; and isopachic curves from boundary stresses and the numerical solution of Laplace's equation. *Jour. Applied Physics*, April, 1939, pages 248–257, 18 illus., many equations.

Direct Optical Measurement of Individual Principle Stresses. J. H. A. Brahtz and J. E. Soehrens. Photoelastic interferometer made by one of the authors and patterned after that used by H. Favre. Theory and method of operation of the instrument are described and improvements made possible by recent advances in optics and plastics are discussed. Instrument has been in successful operation at the United States Bureau of Reclamation's photoelastic laboratory in Denver about three years. *Jour. Applied Physics*, April, 1939, pages 242–247, 6 illus.

A Review of the Photoelastic Method of Stress Analysis. R. D. Mindlin. Principles of stress, strain and optics are discussed covering: definition of stress; stress specification; principal stresses and principal planes of stress; small strain and components of strain; analogy between stress and small strain; stress-strain relations; propagation of light in isotropic and crystalline media; stresses in a plane; stress-optical relations for two-dimensional photoelasticity. Photoelastic materials, models, and loading machines are described.

Measurement of the difference between and the directions of the principal stresses is dealt with covering: fundamental components of the photoelastic polariscope; color comparison; tension compensator; quarter-wave plate compensator; quartz-wedge compensator; spectroscopic analyzer; large field polariscopes; isochromatics; isoclinics; isostatics; and isotropic points. To be concluded. *Jour. Applied Physics*, April, 1939, pages 222–241, 35 illus., 1 table, many equations.

Aircraft Accessories

The Problem of Ancillary Power Services on Aircraft. R. H. Chaplin and F. Nixon. It is proposed: to retain electricity and hydraulics only; to drive generators for these two services off main power unit or units; to standardize a pressure for hydraulic service this pressure to be as high as is practicable (3000 lb./sq.in. for brakes and jacks and 1000 lb./sq.in. for gun turrets); to retain direct current at 24 volts for electrical service. To adopt, as an interim measure, generation of pneumatic energy, where necessary, by small electrically-driven pump unit until new equipment becomes available.

Discussion covers: reasons for supplementing electricity by hydraulics replacement of vacuum and compressed air and reasons for their elimination; independent power unit for services; high-frequency high-voltage alternating current and that of normal voltage and frequency; main power unit or units as source of energy; electrical and hydraulic generators; review of hydraulic situation; emergency operation. The engine viewpoint is also discussed. Appendices include: list of power services on aircraft; basic source of power; characteristics of hydraulic pumps in service; and descriptions of various types of accessory gearboxes; auxiliary power units. *Royal Aeronautical Soc., Preprint for Meeting*, March 30, 1939, 32 pages, 11 illus., 3 tables. Paper and discussion following. *Flight*, April 6, 1939, pages 357–359, 3 illus. Discussion, *Flight*, April 13, 1939, page 379.

Aircraft Maintenance

Large-Scale Maintenance. Original maintenance ideas in the British Airways shops at Heston, scientific airline operation, and fixed wing-tip slots for the Lockheed 14 transports are described. Slots are said not only to prevent premature wing-tip stalling but also to provide much more adequate aileron control at and near the stall. It is understood that Hudsons, military versions of the 14, are being similarly modified. *Flight*, April 6, 1939.

Aircraft Manufacture

The German Production Film. Series production of the Junkers Ju 86-K military twin-engined airplanes and of Junkers Jumo 205C heavy-oil engines is illustrated in photographs taken from the sound film of the Junkers Flugzeug- and Motorenwerke entitled "Metallene Schwingen" which was shown at a meeting connected with the Salon de Paris. Photographs are discussed with comments on mass production in Germany. *L'Aéronautique*, February, 1939, pages 49–54, 10 illus.

Production Phases of Flush Riveting of Airplane Fuselages. D. R. Berlin. Development of new techniques and new tooling at the Curtiss Aeroplane Division, which has resulted in the adoption of flush riveting of airplane fuselages at the added cost of only about 30 percent. Changes in countersinking which eliminated the cracking of the second sheet included: redesign of the rivet; elimination of redrilling operation in the second sheet; development of suitable press countersinking die angles; chamfering inner edge of extrusion shapes and formed stringers prior to press countersinking, also inner edge of the inner sheet; and use of linseed oil as a lubricant. Spring loaded stake used on a pneumatically-operated toggle squeezer to hold the sheets tightly together during press countersinking and riveting is illustrated. Proper selection of punch and die angles and diameters is discussed with drawings. Rivet-driving tools, combination drill and countersinking tool, and latest unit for setting countersunk head rivets in aircraft fuselages are illustrated and comparative time studies of brazier and flush riveting operations are given. *Iron Age*, April 13, 1939, pages 30–33, 9 illus., 2 tables.

Flush Riveting—Considerations for Quantity Production. D. R. Berlin. Flush riveting development project undertaken by Curtiss Aeroplane Division is described, including: consideration of elements common to brazier and flush riveting; investigating types of flush rivets; experimental development of press countersinking; experimental tooling of punches and dies for use with vibrators, squeezers and one-shot guns; test methods; development of production tools and procedure; scrutiny of actual production to study possible improvements; microphotographs of actual production riveting; and checking production costs. Experiments with press countersinking with the rivet, in lieu of punches, driving rivets by means of one-shot riveting tools, development of a rivet of suitable shape and adequate strength that may be set from one side, particularly for inaccessible riveting, and internal riveting, especially in view of the close quarters in which operations must be performed, are discussed with recommendations for further investigation. Various designs of rivets and tools are illustrated in drawings and time of riveting operations for the various riveting processes is compared. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 32 pages, 42 illus.

Manufacturing Tolerances. H. Parkinson. Tolerances set in the manufacture of aircraft are given, including: standard bolts and pins; drilled, reamed, woodscrew and rivet holes, and holes drilled in wood; shafts, special bolts and pins; profile dimensions; castings and forgings; bolt and rivet holes, centers and locating dimensions; angles; fork and fittings; and control surfaces and levers. *Aircraft Engineering*, April, 1939, pages 165–166, 2 illus., 6 tables.

Quantity Production of the Spitfire 1. Many major assemblies of the Spitfire 1, such as main planes, all control surfaces, engine mountings, and tail units are made by other plants and brought together for assembly at Woolston, Itchen, or Eastleigh. Main assemblies are considered in great detail, one by one, a description of the structure is given, and notes on the jigging and operations in the assembly are included with many illustrations. Descriptions also include: method of planning; control surfaces; rudder construction; production of flaps; cowlings and fairings; and final assembly. Very long article. *Aircraft Engineering*, April, 1939, pages 167–180, 44 illus.

Aircraft

Military Aircraft of the World, Their Functions, Characteristi s and Possible Development. H. F. King. Trends in design, and the functions and newer designs of fighters, bombers, Army-cooperation types, "attack" machines, aircraft armament, transport, target and communication airplanes, trainers, Naval aircraft, coastal-defense aircraft, flying boats, and aircraft engines are discussed in very great detail. Aircraft of all countries are considered and compared, and capabilities of aircraft now in service, or about to go into service are covered. Three-page table gives characteristics, armament, and performances (wherever possible) for the following: 37 British, 47 U.S., 4 Canadian, 27 German, 4 Czechoslovakian, 39 French, 19 Dutch, 9 Belgian, 33 Italian, 7 Polish, 6 Russian, 7 Jugoslavian, 2 Japanese, 1 Lithuanian, 3 Rumanian, 1 Finnish, and 1 Hungarian military aircraft. Lockheed Allison-engined fighter, Bell Airacuda, and new models of other countries are referred to. *Flight*, March 30, 1939, pages 307–314, 314a–314c, 314f–314j, 323–332, and 335–338, 150 illus., 1 table.

Slots for Lockheeds. British authorities are seriously considering the fitting of wing-tip slots to the Lockheed Hudsons for the R.A.F. Apparently there is some discussion of the type to be used—fixed slats as on the North American Trainer, slots slit through the wing just behind the leading edge, as propounded and used by Col. V. Clarke, or slots of the fully automatic Handley-Page type. Most likely choice appears to be the slit type. Arguments against the slit type are given. "Already Lockheed 14s of British Airways are having slots cut into the wing tips in front of the ailerons in the way which—is more efficient than the 'eyebrow' slots as used on the N.A. types. Although experienced pilots who have flown the 14 for a considerable number of hours—grow to like and respect the breed, it is definitely not a type that even a fairly experienced pilot can fly safely without some hours of dual instruction. Its two troubles are the very tapered wings—and the large travel of the centre of pressure when the big Fowler flaps are extended." Note dealing also with the automatic slot which "on very fast airplanes is not so good as the type which is controllable." *Aeroplane*, April 5, 1939, page 518.

Diving Brakes. "The U.S. Navy, which sets great store by dive bombers, is going in for 'double-split' flaps on the trailing edge. It appears from limited information available that the two halves of these flaps diverge like leaves of an open book." References only are made to air brakes used to reduce speed in a bombing dive as follows: double-split flaps on trailing edges of the Curtiss SBC-3 dive bomber; double-split perforated flaps on the Brewster dive bomber; air brake on the Fokker G-1 restricting its speed to about 300 m.p.h.; and special flaps on the Blackburn Skua. Junkers concern's brief explanation for the air brakes fitted to their Ju.87 two-seater dive bomber (actually small flaps just behind the leading edge) is given. It is claimed that the Fokker G.1, during a 3000-ft. dive can do a 180-degree aileron turn. Short article. *Flight*, April 13, 1939, page 378d, 3 illus.

BELGIUM

A New Trainer. Tipsy tandem two-seater training monoplane (130 hp. D. H. Gipsy Major engine), designed for the Belgian Air Force has been produced by Avions Fairey. Particular care has been taken with design of tail unit to guard against spinning troubles. Tipsy M is fully stressed for acrobatics. Maximum speed 150 m.p.h. Cruising speed 125 m.p.h. Minimum speed with flaps 47 m.p.h. Landing speed 44 m.p.h. Service ceiling 19,650 ft. Climb to 3281 ft. in 4 min. Range at cruising 470 miles. Short description, characteristics, performance. *Aeroplane*, April 12, 1939, page 459, 1 illus.

CZECHOSLOVAKIA

Aero A-300 Twin-Engined Bomber. Aero A-300 twin-engined day and night bomber and long-distance reconnaissance airplane (two Bristol Mercury IX 830-hp. engines, Hamilton variable-pitch three-bladed propellers). Maximum speed 470 km./hr. at 5500 meters. Climb to 6000 meters 11 min. 35 sec. Range at cruising speed 900 km. Characteristics and performance. Interior of nose turret and exterior views shown.

Aero 304 twin-engined three-seater airplane may be used for the following missions: Reconnaissance (two machine guns, range 1200 km. at 70 percent maximum power, total load 1355 kg.); light day and night bombardment (300 kg. bombs, same range, 3 machine guns); training for observers, bombers and gunners and in piloting high-speed twin-engined airplanes; and photogrammetry with special equipment. Two Walter Super-Castor 1-MR 430-hp. engines. Maximum speed 322 km./hr. at 2000 meters. Climb to 4000 meters in 19 min. Description, characteristics, performance, and armament for different missions. *L'Aérophile*, February, 1939, pages 32 34, 6 illus., 2 tables.

FRANCE

Bréguet 690 Light Twin-Engined Bomber. Bréguet 690 is a midwing airplane entirely of metal except for the cloth covering of the movable tail surfaces. Airplane may be equipped with either two Hispano-Suiza 14 Ab or two Gnôme Rhône 14 Mars engines and armed for: mission C.3—fighter command (protection of bombers); mission B.2—light bombardment (2 bombs of 200 kg.); mission AB.2—attack on the ground and light bombardment (8 bombs of 50 kg.); and mission A.3—observation and reconnaissance. Maximum speed 440 km./hr. at 2000 meters, 500 km./hr. at operational altitude. Climb to 4000 meters in 7 min. 30 sec. Theoretical ceiling 9500 meters. Description including armament and arrangements for the various missions, and characteristics and performance. *L'Aérophile*, February, 1939, pages 31–32, 2 illus., 1 table.

Dewoitine D-342 Trimotored Transport. Dewoitine D-342 all-metal 24-passenger transport airplane. Three Gnôme-Rhône 14 N-17 950-hp. engines. Maximum speed 370 km./hr. at 1750 meters. Cruising speed, at 2000 meters and 65 percent power, 320 km./hr. With one engine stopped

speed at 1750 meters 312 km./hr. and theoretical ceiling 5700 meters. Characteristics and performance. *L'Aérophile*, February, 1939, page 36, 2 illus., 1 table.

GERMANY

A Record-Breaking Bomber. New speed record of 321 m.p.h. for a distance of 621 miles with load of 4410 lb. was recently made by a German Junkers bomber (two 1100-hp. Junkers Jumo 211 gasoline-injection engines). Airplane is a prototype of a new bomber to be produced in series for the German Air Force, and is an all-metal low-wing monoplane, probably the Junkers Ju.88. Fuselage seems to be of same form as that of the four-motored Junkers Ju.90, and to have straight slab sides and tapered glazed nose. Two 12-cylinder inverted-vee liquid-cooled Jumo 211 gasoline engines are mounted so that exhausts from inverted cylinders discharge below the wings. Thrust lines appear to lie through the middle of the wing. Radiators are arranged radially around the nose of the motor immediately behind the propellers and are enclosed in short-chord radial cowling with controllable cooling gills all in front of the stub exhausts. Exhausts are arranged to face backwards overlapping each other in the general manner of the ejector-exhausts developed in England. Brief note and photograph of engine nacelle. *Aeroplane*, March 29, 1939, page 391, 1 illus. *Flight*, March 30, 1939, page 333.

Blohm and Voss Ha-138 Defense and Reconnaissance Flying Boat. Blohm and Voss Ha-138 defense and long-distance reconnaissance flying boat. Three Junkers Jumo 205.C 600-hp. heavy-oil engines. Maximum speed 275 km./hr. Cruising speed 235 km./hr. Maximum range 5000 km. Normal range 2400 km. Characteristics and performance. *L'Aérophile*, February, 1939, page 35, 1 illus.

New German Aircraft for Sport, Training, and Touring. C. G. Esche. Siebel Fh-104 twin-engined, Ago 192 twin-engined, and Messerschmitt Bf-108 touring airplanes; Arado Ar-79, Fieseler Fi-99, Klemm Kl-35B, Buecker Bue-180, Siebel Si-202 sport planes; Erla 5D, Erla 6A, and Moeller Bremen Stomo III small airplanes; Buecker Bue-131, Buecker Bue-133, and Focke-Wulf F.W.44 initial trainers; and Arado Ar-66, Gotha Go-145, Focke-Wulf F.W.56, Arado Ar-76, Arado Ar-96, and Focke-Wulf F.W.58 trainers. Design and construction of these airplanes, table of characteristics and performance, and illustrations of airplanes and parts. *V.D.I.*, April 1, 1939, pages 373–379, 22 illus.

Henschel Hs-123 Light Bomber. Henschel Hs-123 is a sesquiplane partly constructed of stamped duralumin sheet. A B.M.W.132 870-hp. engine gives it a speed of 400 km./hr. Specially designed for attack missions the Hs-123 carries 300 kg. of projectiles suspended beneath its wings. Practical ceiling 9000 meters. Maximum speed 400 km./hr. Cruising speed 360 km./hr. Time to climb to 1000 meters 1.10 min. Range 600/860 km. Long description, characteristics, performance. *Les Ailes*, April 6, 1939, page 9, 3 illus.

GREAT BRITAIN

Our New Air Liners. Fairey FC-1 is estimated as able to reach its operating height of 15,000 ft. in 15 min. and to get down in about the same time and thus be able to fly 800 miles out of 1000 at the operating height. Flying at that height on a 1000-mile journey for a given cruising speed, instead of at 7000 ft., will save about 500 lb. fuel. Freight compartments as well as passenger will be within the pressure cabin and pressure, temperature, humidity, and proportions of oxygen and carbon dioxide of incoming air will be strictly controlled. Air at sea-level pressure will be supplied at the rate of 20 cu.ft./min. per passenger. *Aeroplane*, April 5, 1939, page 420.

This Desirable Residence. Short Sunderland flying boat (four Bristol Pegasus XXII engines) offers—on two floors—plenty of home comforts for its crew. Photographs of interior showing a control cabin view (cylinders on the rack are Very cartridges), a member of the crew handling a drogue from the galley hatch, and the navigator at work. *Flight*, April 6, 1939, pages 352b-352c, 4 illus.

British Light Airplanes. "After considerable experiment the General Aircraft Cygnet has been got into a form on which production will go ahead . . . No other light aeroplane is all-metal, including the wing covering; no other single-motored machine has twin fins and rudders; no other machine with such landing gear has yet gone into production." Performance of this tricycle trainer described. *Aeroplane*, April 5, 1939, page 438.

Luton Major strut-braced high-wing cabin monoplane powered with a Walter Mikron I engine. Maximum speed 100 m.p.h. Description of design and performance. *Flight*, April 6, 1939, page 347, 2 illus.

New C.A.G. trainer, the Hillson Helvellyn tandem-seater midwing monoplane, although primarily designed for club and C.A.G. work, is likely to have an all-round performance which will make it suitable for other purposes. It is not expected that spinning will be possible, and for training in this maneuver a larger rudder will be offered for temporary use. Cirrus Minor 80–90 hp. engine. Estimated maximum speed 127 m.p.h. Normal cruising speed 110 m.p.h. Description. *Flight*, March 30, 1939, pages 333–334.

Thirty Short Years. Birth and growth of a famous British aircraft firm. History of the Short Brothers is traced and the designs of aircraft produced are described. Specifications are given for the Sunderland flying boat for the R.A.F. and for the 14/38 civil land plane on which the Company is now engaged. Type A, complete with equipment, will have a tare weight of 39,050 lb., payload and crew of four will account for 8000 lb., and all-up weight will be 71,000 lb. Cruising speed at 10,000 ft. will be 246 m.p.h. Type B will have a cruising speed at 25,000 feet of 275 m.p.h. *Flight*, April 20, 1939, pages 404e-404j, 405–411, 50 illus. See also *Aeroplane*, April 19, 1939, pages 479–492, 46 illus.

HOLLAND

Tests of the Fokker G-1 Twin-Engined Airplane and of Its Air Brakes for Diving Flight. Experiments made in Holland with a Fokker G-1 (two Bristol Mercury VIII engines and metallic three-bladed propeller having two pitches), as reported by Capt. Bjnggren, Swedish Air Force, are discussed. Objects of test were to verify the efficiency of the flaps mounted under the wing of the G-1 for reducing the speed in a dive during attack, and to examine the flying characteristics of the airplane furnished with these flaps. Air brakes are identical in principle to those of the Junkers Ju-82, and are operated hydraulically.

For a wing over at 180° during a dive a trajectory of 700–800 meters appears necessary. Initial speed at 2000 meters was 200–220 km./hr. Dive proper took place over 1000 meters. Speed at the moment of pulling out was 450–460 km./hr. Maximum speed realized in course of the dive was 480 km./hr. but altitude at which speed was made could not be controlled. Loss of altitude at the moment of pulling out was 500–600 meters with an acceleration of 3.5 to 4 g. Minimum altitude of clouds for executing an attack in a dive if there exists a wing over of 180° can be fixed between 1600–1700 meters. If wing over or important corrections are not necessary, a ceiling of 1200 to 1500 meters would suffice. Fokker G-1 is shown with flaps open and closed. *Les Ailes*, April 6, 1939, page 5, 2 illus.

ITALY

Ro-44 Catapultable Pursuit Seaplane. Ro-44 single-seater pursuit biplane of all-metal construction (Piaggio P.X.R. 9-cylinder engine developing 700 hp. at 1000 meters) is armed with two Breda Safat 12.7 machine guns firing from the hub of the propeller. Maximum speed 285 km./hr. Construction, characteristics, performance. *L'Aérophile*, February, 1939, pages 34–35, 2 illus., 1 table.

SAI 2-S Four-Seater Touring Airplane. SAI 2-S monoplane is constructed entirely in wood. Alfa-Romeo 115-I six-cylinder inverted inline aircooled 195-hp. engine. Maximum speed, ground level 250 km./hr. Cruising speed, 70 percent power, 215 km./hr. Range 4 hr. 30 min. Characteristics and performance. *L'Aérophile*, February, 1939, page 36, 1 illus., 1 table.

U.S.A.

Harlow PJC-1. Harlow Private Transport is licensed as a two-place plane but production airplane will be a four-place type. Warner Super Scarab 145-hp. engine. Claimed top speed 170 m.p.h. and cruising speed 160 m.p.h. at optimum altitude. Landing speed 48 m.p.h. with split flaps fully extended to their maximum deflection of 45°. Rate of climb 900 ft./min. Service ceiling 13,400 ft. Cruising range 600 miles. Description, characteristics and performance. *Aviation*, March, 1939, pages 58–59, 3 illus., 1 table. Specifications of the PJC-1, and reference to the PJC-2 four-place with larger tail surfaces, and PC-5 closed-cabin tandem trainer. *Western Flying*, March, 1939, page 24.

Martin Completes Patrol Bomber for U.S. Navy. Martin XPBM-1 twin-engined patrol bomber flying boat has gull-shaped wings to secure maximum propeller clearance above the water during taxiing, taking off and landing, retractable floats and hull sufficiently broad in beam to afford generous passage space between compartments, and complete living quarters for crew. Weight about 18 tons. Wing span 118 ft. Overall length 78 ft. Few details and reference to quarter-scale flying model first built and tested. *Aero Digest*, April, 1939, page 32, 2 illus.

Plane and Engine by Erco. Erco Model 310, developed by F. E. Weick and produced by Engineering and Research Corporation, has tricycle landing gear and simplified control. Linkage interconnects ailerons and rudders permitting the airplane to be flown entirely by wheel control. Ship has been designed to prevent the pilot from holding the wing in a stalled attitude, power on or off. Tail surfaces have been arranged so that airplane will not balance in a spin. Morehouse 4-cylinder inverted inline aircooled engine develops 55 hp. at 3000 r.p.m. at sea level, and 60 hp. at 3750 r.p.m. for take-off. Maximum speed 101 m.p.h. *Aviation*, March, 1939, page 53, 2 illus.

Stinson Reliant for 1939. Twenty-five new aerodynamic refinements and improvements over previous Reliants have added 5 to 10 m.p.h. to the speeds and 40 lb. to the payload. Choice of powerplant range from the 245-hp. Lycoming R-680-D6 to the 450-hp. Wasp Junior or Wright Whirlwind. New type of aerodynamic balancing is incorporated in the elevators and rudder to give improved finger-tip control. Stabilizer is adjustable and trimming tab is provided on the rudder. Cruising speed of the SR-10F (450-hp. Wasp Junior T.B. engine) is 177.5 m.p.h. and cruising range 680 miles. Description of seven new models with specifications for each. *Aero Digest*, April, 1939, page 90, 2 illus., 1 table.

Fast Work. Single-seat racer with retractable undercarriage, built by C. C. Flagg, does 235 m.p.h. on a standard unaltered Pobjoy Niagara I of 90 hp. Highly-tapered monospar wing has a span of 13 ft., maximum chord 48 in. and minimum of 18 in., area being only 24.8 sq.ft. Split flaps are used. Landing wheels are very small. Short description. *Aeroplane*, April 5, 1939, page 429, 2 illus.

The Offensive Trinity. "Visibility, particularly for the pilot and bomb aimer, is a strong point in the design of the new American attack bombers illustrated," the North American NA-40B, Stearman X-100 and Martin 167. Details are given for these airplanes, and it is said that the Douglas (Northrop) B-19 bomber, which crashed with a member of a French mission on board, has been ordered in quantity by the French Government. Photographs are shown of the prototype Consolidated XPBXY-1 flying boat of the U.S. Navy, Bell Airacuda, and, on another page, pilot's instrument panel and radio-navigator's compartment of the Consolidated Model 28 twin-engined flying boat, generally similar to the PBY series supplied to the U.S. Navy. *Flight*, April 13, 1939, pages 378, 378a, 385, 8 illus.

Aircraft Performance Testing

The New Speed Record. Further details of how the Heinkel's 463.9 m.p.h. was established and timed, and description of timing equipment used on the ground. Constructors say the machine "was a landplane which took off from and alighted on an aerodrome measuring 1000 meters in length and 1000 meters in width; the record machine is no racer but a fighter available for the German Luftwaffe; no special engine was constructed, but a normal Daimler-Benz D.B.601 was used." This is questioned by the editor. "By further refinement of the aerodynamic form, and by improvements in the V.D.M. airscrew, we succeeded in materially increasing the performance without increasing the power of the engine."

F.A.I. regulations for speed record are outlined and an account of the flight is given. Drawings show film and oscillograph strips and method by which the time is read off against the image of the machine, and a diagrammatic representation of the Askania timing system. Timing of the record was done with special outfits designed by the Askania Werke of Berlin. Askania ciné cameras were of the "slow motion" (actually high-speed) type in which as many as 100 frames per second can be taken. *Flight*, April 20, 1939, pages 395–396, 6 illus.

Aircraft Assisted Take-Off

Cutting Out the Aerodrome. F. W. King. Undercarriage-less aircraft proposed would alight on the water and would be launched from the water by means of a launching gear consisting of a light platform supported by two hydroplane floats. Arrangement proposed for the launching gear is similar to the understructure of a twin-float seaplane, except that floats should be longer and more widely spaced in relation to the aircraft. Mounted on each float, immediately behind the wings of the aircraft, are two or more aircraft engines and propellers which form the means of propulsion of launching gear.

Aircraft is supported upon the launching gear in flying attitude until flying speed is reached when it is released. Launching gear never leaves the water. In-draught, due to location of propellers of launching gear behind the airplane wings, causes a greater lift than that due to land speed. Launching-gear floats, being designed for water performance only, may be more efficient than floats of a similar seaplane. Author's patent application is described in detail and military advantages of such assisted take-off are pointed out. Circular canal of 200 yd. width and one mile in diameter is considered sufficient for operating much larger aircraft than the Empire boats. *Flight*, April 13, 1939, pages 382–383, 2 illus.

Aircraft Accidents

The "Cavalier" Report. Descent between New York and Bermuda on February 28 was attributed entirely to complete loss of power of the two inner engines and partial loss of power of the outboard engines owing to carburetor icing troubles. Sea conditions were such that a safe landing was impossible, and, as a result of damage to the hull, machine sank in about 15 min. after breaking in half. Investigating board report recommends that system of throttle and mixture control used must have aggravated the trouble caused by icing and should be studied. Flying boats of this class should be modified so as to give the crew more adequate control of air temperature, and, for emergency conditions, an additional supply of heat should be provided to raise the temperature of the incoming air before it reaches carburetor jets. Carburetor or temperature indicator is essential. *Flight*, March 30, 1939, page 317. Facts, flight, crash, and fading and carburetor icing troubles are discussed in detail with recommendations made. Long report. *Aeroplane*, April 5, 1939, pages 432–433.

"Keep Your Nose Down." Fifty-one out of 98 crackups may be charged to flying nose high. Analysis of the 98 accidents recently reported by the Air Safety Board reveals that the majority could have been avoided if the pilots involved had recognized a few old rules so fundamental that they have been accepted by the flying profession as axioms. Rules and violations resulting in accidents are quoted. *Western Flying*, March, 1939, page 15.

Two Reports of Accidents. Long Brazilian report on the crash of the Junkers Ju52 Guaraci flying boat at Santos, and report of the crash of the Lockheed 14-H bimotor in the United States.

First accident was said to be due to insistence on the part of the pilot on landing under unfavorable conditions at sea after having passed over more protected spots, and to the reduction of output of the engine-propeller groups. The Guaraci had three BMW-132 635-hp. engines and carried 15 passengers. Report goes into the voyage to Santos, the accident, the rescue, the airplane, the cargo, atmospheric conditions, crew, and conclusions giving two hypotheses. *L'Aérophile*, February, 1939, pages 37–42, 1 illus., 2 tables.

Aircraft Refueling in Air

The Large Flying Boat and Air Refuelling. "If refuelled weight were increased to 280,000 lb. and the cruising power to 66 percent max. b.hp., the speed would be increased to 190 m.p.h. and the payload by 74 percent. This, however, might present some problems in capacity unless the hull were redesigned to suit it." Improvement in revenue-earning capacity made possible by refueling in flight is investigated for the case of the flying boat proposed by I. I. Sikorsky which would take off with 100 passengers on 12,000 b.hp., having a range of 5000 miles at a cruising speed of 187 m.p.h.

Parts of Sikorsky's Lilienthal Gesellschaft paper entitled "Trends in the Design of Large Flying Boats" are quoted and his opinion that "assisted take-off has no justification for aircraft of 40 tons or more" is refuted as it regards refueling in flight. Weight analysis is given for a boat similar to the Sikorsky, taken off at the same loading but refueled in air to 256,666 lb. and carrying 140 passengers. Transport airplane or bomber, at the end of its useful life in that capacity, may still be converted into a refueling tanker. The Sikorsky S.42 Clipper would probably be useful to tank up the Boeing 314. *Flight*, April 6, 1939, pages 342–344, 3 illus., 1 table.

Air Transportation

Blue Ribbon Battleground. Intergovernmental aspects of the North Atlantic trade route to be flown by Pan American Airways, and preparations which have been made. Description entitled "How the Atlantic Will Be Flown" deals with training of crew, exterior and interior views of the Boeing 314 Clippers to be used by Pan American on the North Atlantic airway, route and weather, and radio services are described. *Aviation*, March, 1939, pages 27–31, 33–36, 39–41, many illus.

Civil Aviation Abroad—Denmark. P. H. Pearson. Private flying, scheduled air transport (international and domestic routes and air mail services), miscellaneous operations, flying schools, airports, aircraft production, aids to flight, administration and regulation of civil aviation, and market for civil airplanes. *Aero Digest*, April, 1939, pages 62–63, 106, 109, 5 illus.

Good Neighbor Skyways. Aviation trade route map of Latin America shows present routes and those surveyed but not yet in operation. United States, British, French, Dutch, German, and Italian routes throughout South and Latin America and their connections to the United States, Africa, and Europe are shown. Two smaller maps show routes operating in 1929 and 1934. Chart compares Pan American Airways and domestic lines of the U.S. for each year since 1929 in regard to miles of route operated, number of radio-weather stations, number of airports, and miles flown annually. Weight and cost of planes used by Pan American for the last eleven years are also indicated. Aviation trade route map of Asia and Australia with connections to the United States, Europe, and North Africa, and also a map of trade routes of the North Atlantic are given. Larger number of ocean miles logged by Pan American in comparison with mileage of Germany, France, and Imperial Airways is shown. *Aviation*, March, 1939, page 20–22, 24, 25, 26, 9 illus.

The French Atlantic. Early next year Air France-Transatlantique should have three trans-oceanic flying boats comparable in size and performance with the Boeing 314. These are the Latécoére 631 (66 tons all-up weight) and two S. E. 200s (60 tons each). They will be put on the route between Biscarosse and Port Washington, calling at the Azores. These three machines will probably be powered by six American engines, in each case, as the only suitable engines for these aircraft are considered to be the Pratt and Whitney 1400-hp., Twin Hornet and Wright Cyclone of 1500 hp. Brief reference. *Flight*, April 13, 1939, page 381.

Pan-American Preliminary. First 1939 Atlantic flight over the Azores route by the Pan-American Airways' Boeing 314 "Yankee Clipper." Long description of the flight, of the flying boat, and of its radio and other equipment from the British point of view. Among the photographs are those of the crew's flying quarters, navigator's table, and engineer's controls and instruments. *Flight*, April 13, 1939, pages 370–373, 385, 9 illus.

The Reserve Route Flight. Proposed survey of Imperial Reserve Route airway across the Indian Ocean which has never been crossed by aircraft. Survey is to be made by Richard Archbold in his Guba Consolidated P. B. Y. flying boat, Capt. P. G. Taylor in charge of the survey, and others. *Aeroplane*, April 19, 1939, page 496.

Trans-Canada Progress. Organization and development of Trans-Canada Air Lines Corporation to put into operation the main trunk airline across Canada (3500 miles of airway). Airway and airport facilities, flying equipment, training of personnel, servicing, and services in operation are also discussed with a map showing the airlines. *Aeroplane*, April 12, 1939, pages 463–465, 3 illus.

Airships

Recovery of Water Ballast in the LZ-130 Graf Zeppelin Airship. F. Sturm and G. Molt. Necessity for ballast recovery in airships; various procedures for ballast recovery, including water ballast scooping from sea or lake, use of water vapor of the air, water vapor as auxiliary fuel for Diesel engines, swiveling propellers and hydrogen engines; obtaining water ballast by cooling of exhaust gases (mathematical fundamentals); and installation on the LZ-130, its working requisites, and operating results. *V.D.I.*, April 15, 1939, pages 427–432, 11 illus., equations.

Parachutes

Maneuverable Parachute. Eagle back-type parachute is easily maneuvered in a horizontal as well as a vertical plane so that jumper descends at an inclined angle. This feature is achieved through shape of canopy and design of chute which is so arranged that passage of air into the canopy flows toward the rear where it leaves the canopy and passes out of two vent-like tails. Each vent operates independently and jumper can close or open either at will. With a vent closed collected air in the canopy flows out of the open vent and produces a turning movement in the canopy to give the jumper his desired direction of descent. Short description. *Aero Digest*, April, 1939, page 94, 1 illus.

Armament

The Development of Ballistics in the Last 25 Years. O. V. Eberhard. Status of ballistics in the year 1912; basic effects of German tests on ballistics (influences of projectile form and angle of departure); necessity for mathematical determination of the necessary departure angle on the day of firing before beginning firing; initial velocity; air pressure at the ground; "ballistic weight of air"; ballistic "wind"; temperature at altitudes and effect of research, including new calculating processes, antiaircraft firing tables, and mechanical-electrical calculating machines. *V.D.I.*, April 15, 1939, pages 422–426, 1 illus.

Propellers

Alfa Romeo Constant-Speed Propeller. Infinite blade pitch (feathering) and negative blade pitch (propeller braking) may be obtained with the novel Alfa Romeo constant-speed propeller described. Control mechanism is composed of gearing and achieves a very rapid variation of pitch, around 3° in a second, utilizing a very low-power electric motor which absorbs as little as 1.5 amp. due to which the feathering and braking are obtained in a very short time. To avoid inertia effects during control of pitch, the motor is furnished with an electromagnetic brake which stops as soon as the current is cut. Motor is fixed and does not turn with the propeller. A centrifugal regulator assures a constant speed of the motor. Design and installation on an engine are described. *Les Ailes*, April 6, 1939, page 8, 1 illus.

Automatic Prop Synchronizer. Hamilton Standard device synchronizes engines by adjustment of propeller pitch. Generator of the master engine supplies current to one winding of a differential motor controlling speed of the second engine. Current for the other winding of the latter differential motor comes from the generator of the second engine. Changes in frequencies of the two windings cause the motor to rotate which changes propeller pitch until the engine speeds are equalized. Description. *Aviation*, March, 1939, page 60, 1 illus.

Wooden Blades for Controllable-Pitch Airscrews. Wooden blades of Rotol controllable-pitch propellers are being produced in very large numbers by the Airscrew Company for use on many of the latest and best military aircraft. Use of wooden blades may save as much as 50 percent of the weight on blades designed for high powers or as much as 1000 lb. on a four-motored transport. Aerodynamic shape of these blades can be adjusted far more easily and nicely than shape of metal blades and they can be designed for maximum efficiency without having to rely on a limited number of forgings. Wooden blades develop their greatest thrust at lower rotational speeds than metal blades. Wooden blades have compressed roots and Schwarz plastic covering. Description of production process with illustrations. *Aeroplane*, April 5, 1939, pages 430–431, 12 illus.

Wooden Blades for Controllable Props. Composite wood and plastic propeller blades originally developed by Schwarz Company in Germany have been investigated in the United States and are now being produced by Engineering and Research Corporation. About 40 experimental wood and plastic blades have been made for propellers with diameters ranging from 6 to 16 ft. An ATC has been obtained on an 8-ft. diameter adjustable-pitch propeller rated at 300 hp. and weighing 41.5 lb. Brief description of the Schwarz process. *Aviation*, March, 1939, page 57, 2 illus.

A Constant-Speed Airscrew for Motor Cannons. Constant-speed fully-feathering mechanically-operated electrically-driven propeller produced by Constant Speed Airscrews, Ltd. Designers of the VDM propeller set out to produce a fully-feathering propeller which would allow the axial mounting of a "cannon." Whole of pitch-changing mechanism is mounted in the back of the propeller hub, mechanism being driven by an electric motor mounted on the nose of the engine. Very long detailed description of propeller mechanism with drawing, and methods of production. *Aeroplane*, April 12, 1939, pages 456–459, 8 illus.

Feathering Propellers in Airline Operation. M. G. Beard and E. W. Fuller. Entire study of propeller deicing has been placed in a new light by results of these observations of ice deposits on propellers feathered in flight during actual atmospheric icing conditions. End point of ice on the blade is about at the engine cowl diameter and remainder of blade to the tip is entirely free from ice. Ice is all on the leading edge and there is no ice on either face of the blade. Types and installations of the electric constant-speed and feathering propeller are described in detail and compared with hydromatic propeller types. Performance and safety on transport aircraft are considered, and the study of the icing problem by utilizing the feathering feature of hydromatic propellers under actual icing conditions in flight is described. Further research on certain features is suggested. Large four-engined airplanes might advantageously utilize negative thrust of the two inboard propellers to assist the brakes at the end of landing roll. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 16 pages.

Photographing Air-Screw Sound Waves. Photographs of pressure waves in the neighborhood of a propeller were taken by the direct shadow method using a spark giving exposures of about 1 millionth of a second and controlled by the propeller itself. Variable-pitch propeller of 2-ft. diameter driven by a compressed-air turbine was used. Photographs showed the black shadow of the propeller blade with curved images of the sound waves. Trailing vortex from blade tip and an eddying wake behind the blade are revealed, being more distinct at high speeds than at low. There is no definite lower limit to speed at which they can be photographed. Very short abstract, *Proc. Roy. Soc.*, December 22, 1938. *British Jour. Photography*, April 21, 1939, page 251.

Miscellaneous

New York University Laboratories. H. E. Blank, Jr. Equipment and practical research on automotive and aircraft problems for manufacturers and inventors. *Automotive Industries*, April 22, 1939, pages 526–529, 537–538, 11 illus.

The I. Ae. S. Annual Meeting. A. Klemin. Professor Klemin's comments on the papers presented at the seventh annual meeting of the Institute of the Aeronautical Sciences dealing with the subjects of structures, aerodynamics, airplane design and power plants, and reviewing the discussion taking place during the aeronautical symposium. *Aircraft Engineering*, April, 1939, pages 153–157.

Equipment

Buyer's Log Book. Ryan Universal exhaust manifold joints. Cuno Auto-Klean high-pressure filter for hydraulic oil. Martin "Fuel Cell" vibration-proof fuel containers. New Pioneer magnetic pilot's compass based on Air Corps Model B-17. Portable battery-operated light for emergency night work developed by U-C Lite Mfg. Company. "Aero-Thread" screw with spirally-wound insert providing bearing for screw in light alloys. Dardalet engine-mount bolts. Black and Decker Load-O-Meter applied to aircraft. Short descriptions of this equipment. *Aviation*, March, 1939, pages 66–67, 87, 7 illus.

Self-Locking Features Common to New Screw Fasteners. New Dardalet self-locking screw thread has a relieved profile stepped at the midpoint to give a free spinning nut in the unlocked position. Locking stresses are developed by the thread roots and are approximately at right angles to bolt tension, making the lock independent of bolt tension or vibration.

Self-locking features in the form of serrations on the two upper threads have been added to the Unbrako hollow set screws developed by Standard Pressed Steel Company. Shakeproof Hi-Hook thread-cutting screw is provided with a double-width slot for cutting plastic compositions and a screw with a standard slot is available for use in metals. Descriptions. *Iron Age*, April 6, 1939, page 88, 5 illus.

New Equipment (Miscellaneous). New Fafnir series bearings (KH and DH) of the extra heavy capacity type are available in a range of sizes making them adaptable to large aircraft, ratio of bearing capacity to bolt shear strength being extremely high. Aero-Thread screw thread system uses a spirally wound insert or bushing of precision-formed high-tensile bronze spring wire fitting into the tapped hole in such a way that once it is installed it becomes a fixed part of the hole. Descriptions. *Aero Digest*, April, 1939, page 93, 4 illus.

Aircraft Instruments and Navigation

Abstracts. Rellumit fuel gage for aircraft, developed in France, makes use of the carbon-disc resistor. General principle consists in weighing a receptacle contained in a fuel tank and so arranged that fuel level is the same as that in the tank. Weight of receptacle is sustained by the carbon pile whose resistance varies with the force with which its discs are pressed together. Abstract from *La Technique Moderne*, March 1. *Automotive Industries*, April 8, 1939, page 477, 1 illus.

New Static Head. New static tube for aircraft, with a diameter of 2.36 in., permits true measurement of static pressure on aircraft flying at 32,800 ft. at speeds up to 435 m.p.h., and thus of flying altitude. Two openings are provided at the spherical head of the tube, and pressures at both openings are independent within a wide cone of the direction of airflow. One opening is arranged centrally in a venturi tube and takes pressure which is greater than static pressure and pressure in the other is lower than static pressure. Openings are connected by way of three chambers. Apertures between annular chamber and central chamber are calibrated so that loss of energy of air is identical on the way from annular to central chamber. In the latter which is connected with the barograph, static pressure prevails. Short description, in English, from first technical report of the French N.A.C.A. (Groupement Français pour le Developpement des Researches Aéronautique). *Interavia*, March 24, 1939, pages 3–4, 2 illus. on suppl. sheets.

Technical Notes. Vibroscope invented by L'Hopitault and Quintric for use in detecting irregularities in engine operation may also be used for listening to gyroscopes operating in aircraft in flight. When the microphonic antenna is supported on the case of a Badin or directional gyro one hears a continuous musical sound if the gyro is operating normally. When any irregularity occurs, the note is modulated and the sound rises and descends. One can tell them by quickly listening to the gyroscope in operation whether the equipment is in good operating condition or not. Current of the microphonic antenna is transmitted by cable to a control box permitting setting of the power. Sound detection is made by means of helmet for the observer. Brief note. *Les Ailes*, March 23, 1939, page 7.

Tell Tale. T. P. Wright. Curtiss-Wright "Tell-Tale" device makes possible, in a very simple manner, an immediate check on 47 devices, its two major functions being a warning of malfunctioning of instruments and an indication of the setting of controls. Explanation of how the Tell-Tale indicating system works is given and layout of connections on the airplane is illustrated. *Aviation*, March, 1939, pages 54–55, 87, 3 illus. Description. *Western Flying*, March, 1939, page 23, 1 illus.

Navigation

Equations for Great Circle Track. T. P. Conlon. Simplified layout method for the great-circle track, described in the December issue, leads to a new set of equations for a computation of elements of the great-circle track. Equations allow a choice of either latitude, longitude, distance, or course as a determining factor for beginning the computation of the position of the intermediate points. After latitude of the vertex has been computed, equations are adapted for logarithmic computation and schedule-like listing of the latitude, longitude, distance, and course for a number of intermediate points. Computation and listing are made as part of one schedule. *Aero Digest*, April, 1939, pages 77–78, 110, 5 illus., 4 tables, many equations.

Electrical Equipment

The Application of Electrical Equipment to Aircraft. O. F. Olsen. Limitations of and progress being made in developing the most essential materials that enter into physical devices and equipments utilizing electric current for producing mechanical power are considered. Important specification requirements to be met in applying electric equipment to aircraft are described, covering: temperature range of operation (ambient); type of atmosphere in which equipment will operate; available ventilation; duty cycle; noise requirements; maximum altitude at which equipment will be operated; and additional information required for each motor application, including reversal requirements, speed torque requirements from zero to running speed, whether it is essential for safe operation of the airplane, and proportion of rated motor current to source power available over and above other load that must be operating during period motor is starting. Advantages of d.c. and a.c. equipment are described as well as the use of electronic equipment. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 16 pages.

Fire Prevention

A Report of Studies and Tests to Decrease Aircraft Fire Hazards. A. W. Dallas. Activities of the Technical Development Division of the Civil Aeronautics Authority in connection with aircraft fire hazards are reported, covering: tests on fuel dumping; tests in the free airstream; tests with an airfoil placed in an airstream; tests to determine extent of the combustible gas envelope surrounding the liquid fuel; tests on ignition of gasoline by static discharge; and tests on explosions in dump ducts. Tests to determine means of safeguarding aircraft from the dangers associated with powerplant fires are suggested, and present tests and those contemplated are referred to. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 7 pages, 1 table.

Testing Apparatus

Testing Machine for Aircraft Struts. Avery testing machine accommodates specimens up to 10 ft. long and has a capacity of 50 tons, testing aircraft struts in compression. Tests can be carried out by one operator. Arrangement comprises a pumping unit, a straining unit and a load indicating unit. Oil is used as the pressure medium. *Engineer*, March 31, 1939, page 414, 1 illus.

The Month's New Instruments. New devices for measurement, inspection, testing, metering and automatic control. Short descriptions. *Instruments*, March, 1939, pages 76–86, 34 illus.

New Instruments and Tools (British). "Barrier-Layer Type Photocells," E. M. Wender. Tungsram thermionic valves Types EF.8 and EF.9. Southern Instruments Model 440 electrical indicator for pressure, stress and movement. Brabender moisture tester. Milatz Tundall meter for measurement of ratio of light scattered by a liquid medium to that which is transmitted. Short descriptions. *Jour. Scientific Instruments*, March, 1939, pages 94–100, 7 illus., 2 tables.

Workshop Galvanometers. D. C. Gall. High-speed resistance-measuring limit-bridge, light coil type of galvanometer for higher sensitivity, portable d.c. galvanometer, sensitive wall galvanometer with long-scale distance-obtained by multiple reflection, galvanometer for panel work with double reflecting optical system to increase scale distance, small galvanometer unit for use in portable instruments, horizontal type of assembly for test-desk equipment, galvanometer for marine use. Descriptions. *Jour. Scientific Instruments*, March, 1939, pages 69–73, 7 illus., 1 table.

Metals

Properties and Metallurgical Uses of Calcium—A Correlated Abstract. C. L. Mantell and C. Hardy. Calcium-lead alloys, deoxidizing copper and its alloys, calcium in iron and steel, in nickel-chromium alloys, in aluminum, magnesium, and beryllium alloys, and in precious metals. Concluded. *Metals & Alloys*, March, 1939, pages 96–100, 3 illus., 1 table.

Corrosion and Protective Coatings

Protecting Magnesium Alloys. E. G. Savage. Two immersion treatments employing hot chromate solutions were developed at the Royal Aircraft Establishment and are applied to magnesium parts fitted to British aircraft. One is a 6-hr. process and the other a 30-min. process. Bath composition, preparation of material for chromate treatment, stripping, stopping off, tank materials and equipment, and priming coatings as supplementary protectives are described. Lanolin, with or without chromate pigments, and paraffin wax have been found satisfactory but application of light neutral oils has not been found to increase the protection afforded to magnesium alloys by chromate coatings. *Metal Industry*, April 21, 1939, pages 447–449.

Recent Advances in Finishing Equipment and Metal Finishes. F. J. Oliver. Automatic polishing machines, chemically treated buffs, portable sanders, drying enamels by radiant heat, metal cleaning drum, primer for rubber coatings, primers for rusty surfaces, zinc surface conditioner, Seal-Cote transparent coating for metals, enamels and paints, stop-off lacquer for insulating plating racks, porcelain enameling clay, and wear tester for surface finishes. *Iron Age*, April 20, 1939, pages 40–45, 18 illus.

Oxide Films on Aluminum. N. D. Pullen. Physical properties of oxide films on aluminum, produced by anodic oxidation, are discussed, including: composition and structure; X-ray examination; effect of boiling; chemical analysis; flexibility; hardness; and electrical breakdown. British Electrodepositors' Technical Society paper. *Metal Industry*, March 17, 1939, pages 327–329.

Iron and Steel

Cold Forming Operations of Stainless Steels. W. M. Mitchell. Martensitic, ferritic, and austenitic stainless steel composition; various finishes in which stainless-steel sheet and strip are supplied and those preferable for forming operations; physical properties of various types of compositions more frequently used in drawing operations, compared with those of good grade deep drawing steel, as indicated by tests on No. 20 gage sheets; gage of sheet; condition of dies; lubricants; speed of press; surface condition of sheet; and deep-drawing practice. *Am. Machinist*, May 3, 1939, pages 290–292, 2 tables.

Fatigue in Structural Steel Plates with Riveted or Welded Joints. V. P. Haige and T. S. Robertson. First issue—Large Haigh electromagnetic machine, specially designed for investigation of structural problems was used in the experiments described which were carried out at the Royal Naval College. Working with loads up to 8 tons in either direction with a range of variation of fully 6 tons and frequency of 3000 cycles per minute, machine is capable of breaking pieces that would require 25 tons or more in ordinary tensile-testing machines and is probably the fastest of all fatigue machines of comparable capacity. Description of machine and test procedure, and discussion of results, especially of tests of fatigue strength of structural steel plates as used in shipbuilding which were pitted by corrosion in service.

Second issue—Fatigue in riveted joints, and fatigue in welded joints in structural steel. Institution Naval Architects paper. *Engineering*, April 14 and 28, 1939, pages 451–453 and 513–517, 13 illus.

Some Observations on 18-4-1 High-Speed Steel. J. G. Morrison. Observations on the processing of material representative of 702 heats of 18-4-1 high-speed steel. First issue—Effect of trace elements, and information on sweating. Second issue—Other heat characteristics including cold short-

ness, hardenability, undesirable effect of excessive aluminum, susceptibility to decarburization, and possibility of superior heat. It is said that not a single type of hardness testing machine available gives as reliable an index of hardness as the number of inches that may be scratched by a sharp edge nitrided tool on a pane of common window glass. *Iron Age*, April 27 and May 4, 1939, pages 40–45, 59, 10 illus., 1 table.

Colored Stainless Steel. T. W. Lippert. Relative corrosion resistance of colored (Bachite) and untreated Cr and Cr-Ni alloys, of colored (Bachite) 6 Cr steel and untreated stainless (18-8) alloys, and of colored (Bachite) and untreated stainless alloys after tests. Results are shown in tables and tests of over 100 hours are described in detail for these steels. Corrosion resistance of 18-8 is greatly increased by the Bachite process, especially in boiling sulfuric acid, since there is practically no loss in weight. Surface hardness is increased by the Bachite process. Patents dealing with the coloration of steel and the Ludlum and Bach processes are described. *Iron Age*, April 6, 1939, pages 39–45, 79–80, 1 illus., 3 tables.

Surface-Hardening and Hard Surfacing. C. E. MacQuigg. Three types of wear; surface hardening; methods for controlling surface hardness; selecting the hardening process; advantages and applications of flame hardening; flame-hardening steels; flame-hardening methods; hard surfacing; and selecting hard-facing alloy. International Acetylene Association paper. *Heat Treating and Forging*, March, 1939, pages 123–128, 3 illus., 3 tables.

Non-Ferrous Alloys

The Use of Light Alloys in Aircraft Construction. R. LeCoeuvre. Recent developments which have received approval of the aircraft industry are reviewed, including: use of light alloys in engines; improvements in characteristics by heat and cold treatment; development of pressure die casting foundry and of press forging; compression during solidification; use of light alloys in the airplane; forming; methods of assembly; advent of aluminum-magnesium light alloys (alloys containing less than 7 percent Mg, and those containing 7 to 9 percent Mg); use of magnesium-rich alloys; applications of light alloys in construction of seaplane hulls and floats; uses of Vedal or Alclad; electrolytic effects arising; and desiderata for the designers.

Directions in which research will move are predicted covering: improvement of properties of aluminum-magnesium alloys and in particular the fatigue limit; establishment of a good technique of electric welding; heat treatment following electric welding of aluminum-magnesium alloys; water tightness of welded seams; welding control; research on corrosion resistance in sea water. Future developments in the use of light alloys in aircraft construction are outlined.

Reply to discussion of the paper covers: precipitation of the Beta constituent in aluminum-magnesium alloys; reaction to sea water of aluminum-magnesium alloys; use of magnesium-rich alloys, and their resistance to corrosion; use of welding machines; use of steel or brass inserts in certain light-alloy castings; effect of cold hammering on resistance to corrosion of light alloys; resistance of welds to corrosion after treatment; and standardization of light and ultra-light alloys. Appendix deals with the study of heterogeneity in metals and alloys by means of color indications. Process consists of bringing to light the heterogeneities by use of a color indication of pH and reproduction on color prints, some of which are illustrated. *Jour. Royal Aeronautical Soc.*, April, 1939, pages 289–309, 6 illus.

Effect of Work on Non-Ferrous Metals. L. Frommer. Estimation of cold work from X-ray diffraction patterns. If specimen can be examined without having undergone any heat treatment after it has been worked, amount of cold work can be estimated quantitatively to a fair approximation from changes brought about in individual grain reflection spots in monochromatic X-ray diffraction patterns. Fairly close estimation in heat-treated material of amount of cold work imparted prior to heat treatment can be obtained from characteristic changes occurring in X-ray patterns with increasing amount of prior cold work. Characteristics of the patterns, estimation of cold work from changes in the patterns, and limitations of direct conclusions from X-ray patterns are discussed.

X-ray transmission patterns of Hiduminium R.R.56 sheet are illustrated showing influence of cold work (prior to heat treatment) on grain structure forming in heat-treatment by recrystallization, influence of duration of solution treatment upon grain structure, and difference in amount of cold work of Duralumin forgings prior to heat treatment. Surface-reflection X-ray patterns show forging giving better mechanical properties. *Metal Industry*, April 21, 1939, pages 435–440, 5 illus.

Magnesium Alloys for the Industry. A. Kufferath. Production and treatment of magnesium-rich alloys for the aircraft industry are discussed, including: process protected by English patents of Magnesium Electron, Ltd.; process developed by Austro-American Magnesite Co., Radenthein, Carinthia; electrolytic magnesium production in Germany as practiced by I. G. Farbenindustrie-A.G. and Wintershall-A.G. Elomag protective surface layers on magnesium alloys, developed in Germany, are described. Magnewin 3510 and 3512 forgings and castings, machining, turning, drilling, filing operations on magnesium alloys, and four types of welding employed are considered. *Aircraft Engineering*, April, 1939, pages 149–150, 3 illus.

Aluminium and Magnesium Alloys. Non-ferrous metal research being carried out in the Department of Metallurgy, National Physical Laboratory, under direction of Dr. Desch is reviewed, covering: preparation of high purity metals; investigation by means of X-rays; investigation of complex alloys; aluminum alloys; magnesium alloys; intercrystalline cracking; refractory materials; analysis of ancient copper and bronze; and new equipment developed. Abstract of N.P.L. Annual Report. *Metal Industry*, April 14, 1939, pages 424–425.

Cold-Worked Aluminum Alloys. L. W. Eastwood, R. W. James, and R. F. Bell. Relationship of type of microstructure of the aluminum alloy to effect of heating rate was studied. Experimental procedure, results, commercial alloys, microstructure of samples and diffraction patterns are discussed. Long abstract of American Institute of Mining and Metallurgical Engineers paper. *Metal Industry*, April 14, 1939, pages 411–414, 5 tables.

Forging Strong Aluminum Alloys. G. Sachs. Influence of the alloy secondary tensile stresses; forging of discs; forging of impeller wheels; forging of bars; mechanical properties of shaped forgings; the flash in forgings and methods of preventing cracks in the flash; ribs in forgings; and quenching stresses. Long abstract of British Institute of Metals paper. *Metal Industry*, March 31, 1939, pages 366–370, 2 illus. *Heat Treating and Forging*, March, 1939, pages 117–122, 14 illus.

The Institute of Metals (British). Forging aluminum alloys, extrusion of aluminum alloys, hardness and strength of drawn brass rod, and tin bronzes. Very brief abstracts of papers and discussion. *Engineering*, March 31, 1939, pages 403–404. General discussion on "The Effect of Work on the Mechanical Properties of Non-Ferrou Metals." *Metal Industry*, March 31, 1939, pages 370–373.

Testing of Metals

Ad Hoc Research at Derby. New Rolls-Royce research laboratory is designed to speed up work on the development of new materials and to improve processes in the foundry and other processes. Points of interest discussed cover: foundry; X-ray plant; hardness equipment; work being done on effect of electrolyte (from the anodizing bath) on intercrystalline corrosion; tensometer for tests upon specimens 1 in. in length; creep-test machines; fatigue and friction testing machines; machine simulating conditions occurring when a shaft is rotating in bearings; machine for measuring wear when stem of a valve is pushed up and down in a guide; rig in which test pieces mounted on a rotor are blown round by controlled flame to find out hot scaling characteristics; corrosion tests; and damping capacity machine of torsional type. Machines are described and results are referred to in some cases. *Aeroplane*, April 5, 1939, pages 427–429, 8 illus.

Electron Diffraction Examination of Metals. M. L. Fuller. Electron diffraction camera, filament assembly, collimating system, specimen and plate holders, specimen carrier, and electrical apparatus are described in detail. Electron diffraction apparatus designed and built by the author in the Research Division of the New Jersey Zinc Company incorporates features of apparatus developed by L. H. Germer, Bell Telephone Laboratories and by R. Morgan, University of Pennsylvania. *Metals & Alloys*, March, 1932, pages 85–89, 4 illus.

Preparation of Rotating Beam Fatigue Specimens. Q. Henderson and W. B. Seens. Procedure developed in the Research Laboratory of the United States Steel Corporation for forming and finishing specimens to be tested in the R. R. Moore type rotating-beam fatigue machine. Forming operations are facilitated by use of two special fixtures readily attached to standard machines. Special piece of apparatus developed for final longitudinal polishing of the specimen, other equipment and operations are described in detail. *Metals & Alloys*, March 1939, pages 82–84, 4 illus.

Welding

Cracks Caused by Corrosion of a Welded Aluminum Tank. M. Bosshard Corroded tank examined was used for ammonium sulphide solution, aqueous sulphuric acid and soapy water, sometimes hot and sometimes cold. Investigation revealed that inner surface of the plate constantly in contact with tank contents was uniformly roughened by corrosion. At a distance of about 1.6 in. from weld the plate parallel to the weld was cracked through with more or less deep parallel cracks on each side. Half-hard plate was annealed and recrystallized by heat of welding. There was no intercrystalline corrosion. Abstract of report issued by Aluminum-Industrie A. G., from *Korrosion und Metallschutz*, January–February, 1939. *Welding Jour., Welding Res. Sup.*, April, 1939, pages 131 and 152, 1 illus.

Discussion of Review of Literature on Welding Chromium and Chromium-Nickel Corrosion and Heat Resisting Steels. J. T. Catlett. Thinnest and thickest 18-8 steels which can be welded successfully by the atomic hydrogen process are discussed. Intergranular corrosion occasioned by carbide precipitation is also considered. *Welding Jour., Welding Res. Sup.*, April, 1939, page 122.

Elastic Behavior and Strength of Side Fillet Welds. D. Rosenthal and P. Levray. Adequate explanation of the breaking load of side fillet welded joints is to be found in the distribution of unit shear loads within the elastic limit, according to experimental results shown. Distribution is not uniform and load is concentrated at two ends of the weld. When ratio of length to throat of weld is less than 20, concentration of load does not exceed 15 percent. When ratio l/a greatly exceeds 20, concentration of load at ends of welds approaches 50 percent and static breaking load is up to 25 percent less than the law of proportionality would predict. Critique of methods for measuring elastic stresses in side fillet welds, by D. Rosenthal is included in an appendix. Research conducted in 1936–37 at Materials Laboratory, University of Brussels. *Welding Jour., Welding Res. Sup.*, April, 1939, pages 140–149, 28 illus., 3 tables, 16 equations.

The Fabrication and Welding of Stainless Alloys. A. J. Moses. Severe hardening under mechanical working attended by a loss in ductility and a lowering of its corrosion resistance are two principal disadvantages which 18-8 may develop in pressure-vessel operation. Results of an intensive study of 18-8 columbium alloy in connection with fabrication of some relatively heavy wall pressure vessels of this material are given and discussed, with recommendations for the weld metal. Welding of 18-8 molybdenum steel, high chromium irons, stainless chromium alloys, and effect of columbium and titanium additions are discussed. *Welding Jour.* April, 1939, pages 238–240.

Weldability and Mechanical Properties of High-Tensile Steel Sheet. H. Cornelius and F. Bollenrath. Tensile strength of unwelded and gas-welded customary aircraft sheet and several substitutes 0.032–0.047 in. thick containing 0.24–0.32 C, 0.3–1.3 Si, 0.6–1.2 Mn, 0–1.1 Cr and 0–0.3 Mo was determined, as well as tendency to cracking during welding and hardness of welded joints. Requisites (at least 100,000 lb./in.^{2} tensile strength without high hardness and with low Cr and Mo contents) were possessed by a steel containing about 0.3 C, 1.4 Si, 1.2 Mn, 0.25 Mo and by a steel containing about 0.3 C, 0.6 Si, 0.9 Mn, 0.6 Cr, 0.2 Mo. Four other steels could not be considered for practical applications on account of the hardness of the welded joints. Complete tests on commercial melts are necessary to confirm the experimental results.

Investigation was intended to determine properties of cheaper substitutes for the well-known chromium-molybdenum aircraft steel (aircraft material 1452 containing about 0.25 C, 1 Cr, 0.25 Mo). Long Abstract of Report No. 452 of the Materials Committee of the German Society of Ferrous Metallurgy prepared by the Materials Testing Institute of the German Aircraft Experiment Station and published in *Arch. Eisenhuettenwes.*, January, 1939. *Welding Jour., Welding Res. Sup.*, April, 1939, pages 150–152, 4 illus., 2 tables.

Textiles

Manufacturing and Testing of Fabric for Airplane Covering. V. Dietz, Jr. Methods employed by Suncook Mills in producing Flightex fabrics for airplanes. Production processes, test equipment, and procedure are described in detail. Standards required by the U.S. Army and Navy specifications are compared with results of actual test of Flightex fabric on a recent government contract. *Aero Digest*, April, 1939, pages 73–74, 109, 8 illus., 2 tables.

Testing of Materials

Concentric-Cylinder Motor-Driven Viscometer. R. H. Wilhelm and D. M. Wroughton. Design of a motor-driven concentric-cylinder viscometer is presented, essential features of which are continuous operation at a series of speeds, dynamometer mount of the motor eliminating friction to a large degree, and accurate speed measurement by means of a simple stroboscopic

device. Instrument was developed to measure properties of certain suspensions but it is also useful for measuring viscosities of liquids as dealt with here. *Industrial and Engineering Chemistry, Ind. Ed.*, April, 1939, pages 482–486, 5 illus., 1 table.

Siemens Super-Microscope. Electron microscope recently perfected by Siemen and Halske, A.G., will produce images with a magnification of 30,000 which are so sharp that they can be further enlarged three to four times by optical means. Electron rays are emited from an electron tube at a potential of 60,000 to 100,000 volts, then passed through and around the object placed on a very thin collodion film, and finally throw the amplified image upon a fluorescent screen for observation or on a photographic plate. "Focusing" is done by various electromagnetic coils which act like glass lenses in the light microscope. Few details. *India Rubber World*, April 1, 1939, page 59, 1 illus.

Meteorology

A Density Channel for Illustrating Fronts and Occlusions. B. C. Haynes. Density Channel developed at the Boeing School of Aeronautics is 30 × 4 × 6 in., has plate-glass sides and is fitted with metal heating pads on the floor of the channel. Demonstrations of a pure cold front, of the surface and upper fronts of an occlusion, and of a cold front and cumulus formation are described. *Am. Meteorological Soc., Bul.*, February, 1939, pages 37–38, 7 illus.

An Improved Radiobarograph. T. H. Johnson and S. A. Korff. Radiobarograph described is accurate up to 1 mm. Hg pressure and employs a suspension giving increased sensitivity at low pressures and rendering it free from backlash. Instrument and various tests are described. *Rev. Scientific Instruments*, March, 1939, pages 82–85, 5 illus.

Bearings

Metal Sprayed Bearings—Their Use for High-Speed Operation. H. Shaw. Wide range of bearing metals built up by metal spraying were compared in tests with the same metals cast. Tests were carried out at low speeds and at high speed (1000 and 3000 ft./min.) and at loads up to 8000 lb./sq.in. Sprayed metals from France, Germany and America were investigated. New pitted back bearing, tin-coated, which was tested, has a friction that is but a fraction of that of either lead bronze or cadmium silver copper, being a third or a quarter at high speeds. It was not found possible to get seizure at loads below 8000 lb./sq.in. with 1000 and 3000 ft./min. speeds. At 1000 ft./min. seizure did not take place at the 10,000 lb./sq. in. load. Oil channel effect between tin filled pores and copper, combined with porosity of sprayed tin, aids in preserving an oil film even at high speeds. Cracking under impulse loading, influence of colloidal graphite and work in progress on aluminum are discussed. Tests covered babbitt, lead bronze, and cadmium silver copper as well as pitted bearings. Association of Metal Sprayers paper. *Metal Industry*, April 14, 1939, pages 415–418, 2 illus., 2 tables.

Oil and the Bearing. R. J. S. Pigott and P. G. Exline. Concept of the sleeve bearing is presented to show that, in spite of extraordinarily simple mechanical construction of a bearing, its behavior actually is extremely complex and that the assumption that structural simplicity applies to behavior of the bearing has led to endless griefs in design and operation. Term antifriction bearing is misleading. Ball bearing or roller bearing has low starting resistance and torque is not much affected by speed or size. If used for high-speed heavy loads, where friction heat requires a liquid lubricant in quantity to act as coolant, friction losses may be several times those for corresponding sleeve bearings. Losses are described which are due to rolling friction, to ball or roller edge (viscous shear type loss) and loss occurring in a bearing flooded with lubricant or grease flowing readily and getting in the way of balls in excess of slip-lubrication requirements (turbulent type loss). These losses are explained and conditions in roller bearings under load are illustrated. Theory of boundary lubrication and bearing materials are discussed. A.P.I. paper. *Oil & Gas Jour.*, April 20, 1939, pages 258–260, 266, 10 illus.

Fuels and Lubricants

A.C.S. Abstracts of papers presented before the Petroleum Division of the American Chemical Society in Baltimore, April 3 to 5. *Oil & Gas Jour.*, April 13, 1939, pages 40–32.

Rustproofing Greases. Tendency today is to use lanoline products, and based on the work of the D.S.I.R., a number of lanoline rust preventers have been developed, either mineral-oil or white-spirit solutions. Tables deal with the composition, and with the results of accelerated conditions' tests in which lanoline materials obviously stand out as superior to other products. Tables include: commercial lanoline base rust preventers in mineral-oil vehicle, and in spirit carriers; characteristics of some commercial lanolines, average test results for various coatings on mild steel components under humidity conditions, under sheltered outside conditions, and under 20 per cent salt spray. Recommendations are given for preparation of work for finishing, and for application of preventer. *Automobile Engineer*, April, 1939, pages 133–135, 6 tables.

Engine Design and Research

A Review of the Relative Merits of Petrol Injection and Carburetors for Aero Engines. J. E. Ellor and F. M. Owner. Research of the U.S. Army Air Corps on fuel injection, begun in 1925, is mentioned in the historical review introducing the article "The results obtained from these tests seem to have been satisfactory and a considerable amount of flying was done. It was even stated that the Air Corps planned to acquire, after July, 1935, only engines fitted with fuel injection. The reason why this prophecy was not fulfilled has never been stated publicly, but at that time the most difficult part of the system had not been tackled, namely the controlling of fuel supply in flight." Research at M.I.T. and the N.A.C.A. and in England, France, Germany, and Italy is also reviewed. Drawings show: carburetion system of the Rolls Royce Merlin, diagrammatic operation of the Claudel Hobson 85 M. B. Master Control carburetor and fuel injection systems, among them the Marvel system. Authors are with the Rolls-Royce and Bristol companies and engines of these companies are referred to.

Discussion covers: function of modern carburetors; descriptions of the Rolls-Royce S.U. Merlin and Claudel Hobson A.V.T.85M.B. Master Control carburetors, calibration of carburetor characteristics; weaknesses of the modern carburetor system; continuous injection; advantages of timed injection; manifold injection; combustion-chamber injection; and control system. *Royal Aeronautical Soc., Preprint for Meeting*, March 16, 1939, 27 pages, 17 illus., 1 table. Abstracts of paper and discussions. *Aeroplane*, March 29, 1939, pages 405–406, 388, 1 table. *Flight*, March 23, 1939, pages 290, 299, 1 table.

Developmental Work on High-Performance and High-Altitude Aircraft Engines. H. Caroselli. Thermodynamic fundamentals for calculation and comparison of internal combustion engines; fuel-consumption reduction for long-distance flights; performance increase by means of supercharging; determination of the behavior of aircraft engines at high altitudes; torque measurements in flight; simplifying maintenance arrangements of the engine; air-cooled inline engines of higher performance; and sleeve-valve engines. Layout of the single control for gasoline-injection engines (from H. Sachse) is given in a drawing. Among the curves given are shown the mean effective pressure and fuel consumption of gasoline and Diesel engines in slope of the excess air ratio, and a comparison of various altitude performance formulas with the actual performance test. *V.D.I.*, April 1, 1939, pages 385–391, 9 illus., equations.

Fuel Economy Possibilities of Otto-Cycle Aircraft Engines. D. S. Hersey. Problem of the engine manufacturer of reducing engine brake specific fuel consumption at cruising power without limiting take-off output. Economy possibilities under ideal operating conditions in regard to compression ratio, spark-advance setting mechanical efficiency, mean effective pressure, and exhaust-back pressure are considered. Limitations on ideal economy imposed by detonation, and limitations on maximum output imposed by economy requirements are discussed and methods are proposed for improving economy in current engines.

Excellent fuel economy can be obtained from the Otto-cycle engine by operation at high compression ratios, high mechanical efficiency values and optimum spark advance. The limiting factor, detonation, can be suppressed by several means, generally different for cruising and high-output power conditions. It is possible to improve economy on present types of aircraft engines merely by resort to spark-advance control. Reduction of cruising intake-charge temperatures by employment of multispeed superchargers with adequate charge intercooling, also should permit early use of slightly higher compression ratios. Engines designed primarily for economy should be able to develop its maximum cruising output at sea level when unboosted and operated at moderate speeds. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 10 pages, 2 equations.

Permissible Amplitudes of Torsional Vibration in Aircraft Engines. F. Masi, Naval Aircraft Factory. Fixed restrictive limits of amplitude of torsional vibrations; novel system applied by the Naval Bureau of Aeronautics for determining permissible amplitude of torsional vibration; procedure for the calculation of vibratory stresses; and propeller vibration. Naval Bureau of Aeronautics system consists of determining amount of twist produced in the crankshaft when acted upon by a torque equal to rated engine torque, and of using this value, multiplied by a constant factor, for permissible amplitude in torsional vibration. Value of the factor was based on experience with engines designed close to the danger limit and by theoretical analysis. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 19 pages, 6 illus., 5 tables, equations.

Present Prospects for Use of "Safety Fuels" in Spark Ignition Aircraft Engines. F. C. Mock. Program probably necessary before fireproof aircraft fuels can be employed successfully in every day service operations. It seems reasonably certain that fuel of this volatility can be successfully used by injection into the cylinders and possibly by injection into the supercharger. Necessity for fuel economy, difficulties due to low volatility, increased cooling effect of heavier fuel, and specific problems in use of safety-fuel are discussed with recommendations in regard to injection equipment, changes in engine and cylinder, fuel/air metering and power control, starting, installation problems, and injection into the intake pipes, and into the supercharger. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 6 pages.

The Energy Balance Sheet of the Internal Combustion Engine. F. W. Lanchester. First issue—Balance sheet as finally presented depends upon deductions made from an indicator diagram with a knowledge of total energy contained in the charge, and of thermal and other physical properties of the working fluid. Results of J. S. Clarke's series of tests conducted with carbon monoxide gas as fuel are given, criticized, recalculated, and made up into a balance sheet. Crossley Otto engine was fitted with a specially designed hemispherical combustion space. Provision was made for varying the compression ratio, but that of 5.94:1 was given greatest attention. Clarke's method of transforming the coordinate measurements taken from the diagram by aid of logarithmic tables and replotting the logarithms so derived on ordinary squared paper is criticized as being indirect and failing to give readings in terms of pressure and volume in the transformed diagram. Author shows how to determine heat or energy per charge, temperature and quantity of exhaust residuaries present, and, from that and the temperature, how to calculate the heat content, and mean temperature.

Second issue—Construction of the balance sheet founded on the investigations of Dr. Clarke's carbon monoxide test is described in detail with calculations. Institution of Mechanical Engineers paper. *Engineering*, March 31 and April 14, 1939, pages 388–389 and 448–450, 11 illus., 7 tables, very many equations.

Engine Maintenance

Wright Factory Engine Overhaul Depot. Procedures in disassembly and cleaning, inspection, handling of accessories, and facilities for assembly are described. Wright engines are conditioned at the Overhaul Depot located at Caldwell-Wright airport seven miles from the Wright plant. *Aero Digest*, April, 1939, pages 81–82, 6 illus.

Engine Testing

For Engine Research. Heenan and Froude dynamometer plant is specially designed for engine research and development work and differs from that supplied for production testing in that dynamometer is of electric-hydraulic instead of hydraulic type. Hydraulic unit is not controlled by sluice gates between two rotating elements, but there is an ingenious system of varying the amount of water in circulation between pockets of the element.

Gasoline-consumption data can be recorded by weight as well as by flow-meter method. Major part of weighing gear for recording load is housed in the engine test room and not in the control room, only a slender rod connecting the weighing gear with the indicating dial, simplifying soundproofing of control room. Cooling air is supplied to a tunnel by a fan driven by a 975-hp. motor which can deliver a blast of a velocity up to 250 m.p.h. One test plant has been shipped to U.S.S.R. *Flight*, April 6, 1939, pages 363–364, 2 illus.

Measurement of Transient R.P.M. Variations. F. Eckel. For accurate control investigations and for determination of the variable degree of operation of internal-combustion engines, a new type of measuring apparatus was developed in the Daimler-Benz Engine Research Laboratories, by means of which transient r.p.m. variations, inertia free, can be recorded. Apparatus consists of perforated plate located on the tapered end of the crankshaft, light, photocell, damping resistance, and amplifier. Description. *V.D.I.*, April 1, 1939, pages 381–382, 6 illus.

Tchang Te-Lou and Retel Maximeter. Maximeter described was designed at the request of the Service Technique et Aéronautique to furnish information on causes of variations in the running of an engine. Maximeter gives the maximum pressure produced in each cylinder by each explosion or combustion, so that regularity of the operation in all cylinders can be observed and any irregularity in one cylinder can be detected. Maximeter comprises an indicating device having the form and dimensions of a spark plug and a box containing necessary apparatus for measuring pressure. Indicator is mounted directly on the cylinder with connections to the measuring box by electric wire and by a pipe transmitting pressures given by a bottle of compressed gas. Pressure can be regulated by means of controls on the side of the box. When pressure is lower than maximum pressure in the engine, an electric lamp on the box at side of the manometer remains illuminated. *L'Aérophile*, February, 1939, pages 44–45, 2 illus.

Airline Power Control with a Torque Meter. W. G. Lundquist. Mechanical features of some current types of torque meters, used to indicate torque transmitted to the propeller or the torque reaction imposed upon the stationary gear in geared engines, are described including: N.A.C.A. torque meter, reaction type applied to Wright Cyclone engine, and the flow type developed by Pratt & Whitney. Accuracy to be expected, benefits realizable by use of a torque meter for power control, use in long-range cruising and intermediate-range cruising, four different types of cruising flight power control and their revision when using the torque meter, and power control simplification are discussed. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 12 pages, 4 illus.

Engines

Diesel Situation. In Germany, Junkers has produced 2000 heavy-oil Jumo engines of which a hundred equip Deutsche Luft Hansa airplanes and the rest are utilized on long-range military airplanes and flying boats. This production has not stopped and is being pursued methodically. Improvements in each new series from the experiments preceding are shown by increase of power, better endurance and smoother operation.

In England Napier continues its tests on a modified Junkers Jumo 204 and 205, performances of which appear to be superior to those of original engines. Work by Major F. B. Halford and by other English companies, and American developments in Diesel research are mentioned. *Les Ailes*, April 6, 1939, page 7.

Argus As-410 300–450 Hp. Engine. German Argus As-410 12-cylinder inverted-vee air-cooled engine has an output of 450 hp. for take-off at 3250/2150 r.p.m., of 360 hp. at ground level for 5 min., and of 360 hp. at 3000 meters at 3000/2000 r.p.m. Normal power at ground level is 320 hp. Bore 105 mm. Stroke 115 mm. Cylinder capacity 12 liters. Engine and parts such as supercharger are shown in photographs. *L'Aérophile*, February, 1939, pages 43–44, 10 illus.

Hispano-Suiza 14-AB Engine. The 14-AB engine which powers the Potez 63 is a 14-cylinder double-row radial in which an effort has been made to reduce the diameter as much as possible in order to attain an engine-propeller group of a high aerodynamic fineness. Ground-level output 640 hp. Output at 3250 meters with a pressure of 880 mm. Hg 725 hp. at 2400 r.p.m. Weight empty 501 kg. Bore 135 mm. Stroke 130 mm. Cylinder capacity 26.05 liters. Long description with photographs of parts, performance curves and reduction gear drawing. *Les Ailes*, March 23, 1939, page 8, 7 illus., 1 table.

Military Power. Present trends in engine development and probable tendencies. "On at least one Russian bombing machine one engine of 860 hp. is fitted to drive the superchargers of the four 1000-hp. units which provide the motive power." When installed in single-engined machines, engines of over 1500 hp. may demand twin concentric propellers to reduce torque reaction, and the use of an unduly "stilty" undercarriage. Photographs show Rolls-Royce Merlin X with supercharger (1160 hp. at 16,730 ft.); Daimler Benz D.B.600 used extensively in the German Luftwaffe to power high-speed fighters and bombers; Hispano-Suiza 12, France's most successful high-powered liquid-cooled unit, through propeller shaft of which a shell gun may be installed; view from below of the nose of the Junkers Ju.87 dive bomber, one of the new German Service machines using Junkers 211 inverted vee-twelve liquid-cooled engine; Junkers Jumo 205 Diesel engine in a Ju.86K; test installation of a Bristol Hercules 14-cylinder two-row sleeve-valve engine; Napier-Dagger VIII 24-cylinder air-cooled engine; and installation of a constant-speed fully-feathering propeller on a Twin Wasp. *Flight*, March 30, 1939, pages 337–338, 9 illus.

Ranger Aircraft Engine. New Ranger SGV-77OB-6 12-cylinder inverted 60-degree-vee air-cooled supercharged aircraft engine develops 420 hp. up to 5700 ft. altitude. It is approved for take-off rating of 500 hp. on 87-octane fuel, this horsepower being available up to 1700 ft. altitude. Crankshaft is supported on seven main bearings formed integral with upper and lower halves of crankcase. Step-up gearing for blower impeller is divided between two ends of engine. Engine is of geared-drive type, reduction between crankshaft and propeller being in ratio of 3:2. Bore 4 in. Piston stroke $5^1/_8$ in. Displacement 773 cu.in. Compression ratio 6:1. Cruising power 300 hp. up to 10,500 ft. Long description, full-page drawing, and performance curves. *Automotive Industries*, April 15, 1939, pages 500–502, 2 illus.

Sixty Horsepower Aircooled Franklin Engine Developed for the New Light Airplanes of 1939. Franklin Model 4AC-171 direct-drive horizontally-opposed aircraft engine has a maximum normal rating of 60 hp. at 2350 r.p.m. and cruising rating of 42.5 hp. at 2100 r.p.m. Bore 3.875 in. Stroke 3.625 in. Displacement 171 cu.in. Compression ratio 6.25:1. Weight 159 lb. Long description. *Aero Digest*, April, 1939, pages 85–86, 4 illus.

Parts and Accessories

Characteristics of Magnetically-Actuated Fuel Injection Valve. C. J. Vogt and T. A. Rogers. Magnetically-actuated spray valve, developed by Atlas Imperial Diesel Engine Company, offers a means of accurately controlling quantity of fuel injected per cycle and will meter smaller quantities than is possible with any mechanical system, according to test results described. Successive sprays are reproducible. Control of character of spray by simple changes in electrical circuit has great possibilities and governing of injection delay offers no complex problems since system is independent. Common-rail principle is employed with magnetically-actuated nozzle. Although engines in which these nozzles are used employ spark ignition and operate with low compression ratios, system satisfies requirements of Diesel engines. Characteristics of the magnetically-operated nozzle were compared with those of the jerk-pump system. Experimental equipment, fuel valve and electrical circuit are described in detail, and spray development, effect of operating characteristics on fuel injected, and on ignition delay are discussed at length. *Automotive Industries*, April 20, 1939, pages 530–536, 14 illus., 3 equations.

Experience of Icing. W. L. Brintell. Icing experiences, particularly carburetor icing, in the operation of Mackenzie Air Service, Ltd., of Canada, in Latitude 70°. Standard method of heating intake air on the Wright Cyclone engines is described. It is said that the Chandler-Groves carburetor, while it has many advantages, does not dispense with the necessity for air heating. Special devices for winter operation peculiar to the company are mentioned. *Aeroplane*, April 19, 1939, page 499.

Problems in Aircraft Accessory Drives. R. P. Lansing. Problems found in the design of accessory power supplies for the larger airplanes and involvements incident to such design. Accessory drives from main engines and drive by accessory engines are considered. *S.A.E. Preprint for National Aeronautic Meeting*, March 16–17, 1939, 5 pages.

Engine Synchronization. Hamilton Standard Automatic Propeller Synchronizer automatically keeps all the engines of the airplane running at the same speed during flight. Synchronizer can be disconnected and engines controlled manually whenever desired. Description. *Western Flying*, March, 1939, page 34.

Aircraft Radio

Development and Application of Precipitation Static Suppressors. H. W. Roberts. Ejector carried in a tube within tail cone of the airplane, when released by the pilot, permits 5 ft. of thin wire to be drawn out by a small windsock. Thin wire is attached, through the special 100,000-ohm resistor, to a heavier gage wire connecting to the body of the airplane through adjustable air gap condensers. Once released wire cannot be retracted but when lost in landing can be replaced at cost of only 4 cents.

Causes of precipitation static found during United Air Lines' investigations, and static prevention device completed in the Radio Laboratories of United Air Lines after 18 designs had been rejected are discussed. New improved automatic radio direction finder, absolute radio altimeter and collision prevention devices being developed in United's flying radio laboratory are referred to. *Aero Digest*, April, 1939, pages 64, 110, 3 illus.

New Power for Ultra-Highs. "Klystron" which generates hundreds of watts at wave lengths as short as 10 cm. is to have its first trial in connection with the system of blind landing originated by I. Metcalf and developed at M.I.T. with C.A.A. funds. Klystron produced by Sperry Corporation and tested at M.I.T. produced 300 watts at wave lengths between 10 and 40 cm. Description of the klystron, and advantages of its use in the blind landing system. *Aviation*, March, 1939, pages 62–63, 1 illus.

Radio-Telegraphy and Radio-Telephony. C. E. Rickard. New developments in direction-finding services, aeronautical communications, military equipment, and research and development are mentioned in this review of recent progress in radio telegraphy and radio telephony. *Instn. Electrical Engrs., Jour.*, March, 1939, pages 368–379.

Physiology

Altitude Affects Vision. Airplane pilots and passengers flying at high altitudes cannot see as well in dim illumination after looking at a bright light. At 15,000 ft. amount of illumination necessary for vision is 150 percent greater than at sea level. Only five subjects out of 20 remained unaffected at 7400 ft. although psychological tests at that altitude show no reliable changes in mental ability. At 11,000 ft. only one was unaffected and at 15,000 ft. all were affected. All changes were abolished by administration of oxygen. Brief reference only to tests reported by R. A. McFarland and J. N. Evans of Harvard. *Science News Letter*, April 15, 1939, page 238.

Oxygen Mask Developed for Altitude Flying. New type oxygen mask, designed especially to permit passenger air travel at high altitudes is undergoing extensive tests under guidance of its inventors Drs. W. J. Lovelace W. M. Boothby, and A. H. Bulbulian of the Mayo Foundation. Experimental flights were made with non-scheduled passengers to altitudes ranging from 20,000 to 30,000 ft. In the installation in the Lockheed 14 oxygen is piped from a steel bottle to outlets to which masks are attached for use. Oxygen in the bottle is under pressure of 1500 lb. when placed in its compartment at the rear of the airplane. Two valves, developed by Northwest Airlines engineers, step this pressure down to 2 lb. which has been found to be the maximum human beings can stand when taking oxygen. Description. *Aero Digest*, April, 1939, page 105, 1 illus.

Aerial Photography and Mapping

Aerial Photography Service Requirements. J. W. Ninneman. Requirements for aerial photography for land use studies, instances in which these requirements are suitable for other uses, and reasons for the general trend toward more accurate photography. *Photogrammetric Engg.*, January–March, 1939, pages 21–25.

Modern Equipment and Methods in Aerial Mapping. C. S. Robinson. Items of airplane instruments and photographic equipment necessary for aerial mapping. General article. *Photogrammetric Engg.*, January–March, 1939, pages 43–45.

Report on Recommended Map-Accuracy Specifications. Recommendations for specifications for planimetric and topographic map and charts prepared by stereo-photogrammetric processes, are given, covering: control surveys; plotting projections and horizontal control; horizontal accuracy of planimetric detail; vertical accuracy of topographic detail; sheet edge matching; suggestions regarding map testing; reproduction method as to accuracy; plotting originals on larger scale than publication scale; establishing proper contour interval; and designations for various map accuracies. Report of Committee on Map Specifications and Tests. *Photogrammetric Engg.*, January–March, 1939, pages 26–29.